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BUREAU OF ENTOMOLOGY—BULLETIN No. 108.
L. O. HOWARD, Entomologist and Chief of Bureau.

LEAFHOPPERS AFFECTING CEREALS, GRASSES, AND FORAGE CROPS.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Entomology,
Washington, D. C., December 12, 1911.

Sir: I have the honor to transmit herewith, for publication as Bulletin No. 108 of the Bureau of Entomology, a manuscript entitled "Leafhoppers Affecting Cereals, Grasses, and Forage Crops."

This matter was prepared by Prof. Herbert Osborn, professor of zoology and entomology in the Ohio State University, the best known American authority on these insects. Prof. Osborn was a temporary agent of the Bureau of Entomology, and spent about fourteen months in the work, visiting, during the warm months, various parts of the United States, and studying these insects in the field, on the farms and ranches, under natural conditions. He was able to devote his whole time to this work during this period owing to the fact that the board of trustees of the Ohio State University kindly granted him leave of absence for one year. We have, in this document, the first effort made in this country to determine the exact economic importance of these insects, together with the best methods of controlling them.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The present paper is designed to include the general discussion of the group of leafhoppers, with such matter as pertains to the group as a whole and with the consideration of the species which have been recognized as of the greatest economic importance. It deals on this account particularly with those species affecting the cultivated crops, although there are many species which live upon wild grasses and forage plants of the western ranges that undoubtedly have an important relation to the extent of the pasturage they may supply.

A second paper which is in preparation will deal more especially with the more technical aspects of the group, with a discussion of those species which are less noticeable as injurious species or which so far as at present known are confined to wild plants or to those of little cultural value. A knowledge of these is, however, important to economic entomologists, both for the sake of ascertaining their economic relations and as a basis for study in case they transfer their attacks to cultivated crops.

In the collection of material for these papers I have had the hearty interest and assistance of so many different individuals that I hesitate to attempt an enumeration of them, knowing that some must almost certainly be omitted. As stated elsewhere, the work was made possible by the interest of the officials of the Bureau of Entomology at a time when I had an opportunity to leave university duties, and for this interest and constant encouragement I am deeply grateful. At many localities and institutions where I worked I was given not only free access to collections and records, but the direct help of information as to available fields for observation and collection and often the advantage of personal direction and use of conveyances. In this way I am especially indebted to Mr. J. S. McGavren, of Missouri Valley, Iowa; the University of South Dakota; Prof. James Wilson, Brookings, S. Dak.; Prof. J. H. Sheppard, of the North Dakota Experiment Station; Prof. R. A. Cooley, of Bozeman, Mont.; Mr. George I. Reeves, of the Bureau of Entomology laboratory at Pullman, Wash.; Mr. W. J. Phillips, of the laboratory at Lafayette, Ind.; Prof. S. A. Forbes and Mr. C. A. Hart, of the University of Illinois; the Carnegie Museum, Pittsburgh, Pa.; Prof. H. A. Surface and Mr. V. A. E. Dæcke, Harrisburg, Pa.; Prof. Mel. T. Cook, Newark, Del.; Prof. Franklin Sherman and Mr. Z. P. Metcalf, Raleigh, N. C.; Prof. A. F. Conradi, Clemson College, S. C.; Mr. E. C. Cotton, Knoxville, Tenn.;

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A large number of the drawings have been made by the skillful hand of Miss Charlotte King, of Ames, Iowa; and some others, also of her drawing at an earlier period, have been used from the Iowa Experiment Station bulletins with the kind consent of the station officers.

H. O.

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LEAFHOPPERS AFFECTING CEREALS, GRASSES, AND FORAGE CROPS.

INTRODUCTION.

The question of the economic relation of the leafhoppers (Jassoidea) to the various cereal and forage crops has received some consideration, but, in the opinion of those most familiar with these insects, much less attention than their importance merits.

Several factors contribute to this neglect. One is that the work of these insects is so insidious, and its results, except where the insects occur in unusual numbers, so difficult to appreciate by ordinary observation that it is very likely to pass unnoticed.

Another is that the injury caused by these insects is very commonly charged to other agencies, either other insects, parasitic fungi, drought, or possibly even frost, because in many instances the insect itself escapes notice.

Again there are frequently so many species involved in the injury that there has been a tendency, even among entomologists, to consign them all to a limbo of undetermined species, with their habits, life histories, and food relations unknown.

The majority of the species are not only very inconspicuous, often protected by close resemblance to the objects around them, but they are very active, jump quickly when disturbed, are caught with difficulty except in a close-meshed net, and when in flight may be very readily taken for other insects except by a specially practiced eye.

Among many farmers they will pass as the "fly," which usually means the Hessian fly, and in recent years they have been very commonly called the "green bug," by mistaken reference to the Toxoptera, which has had such general notice in the daily press. In some localities, notably in the northwestern wheat-growing section, the term "green bug" has apparently been used very commonly for leafhoppers in the absence of the real Toxoptera.

Under these conditions it is evident that a thorough survey of the situation, an investigation for a number of crops and for all parts of the country to determine the economic status of the group, is desirable.

This is especially true because the means of control for these insects are for the most part to be based on entirely different grounds than for the Hessian fly, green bug, or other insects to which their injury is likely to be referred.

This question has seemed of importance to me for many years. In 1890, in a report to the Division of Entomology,[1] a number of species were treated for the central part of Iowa, and in several other papers issued while I was connected with the Iowa Experiment Station will be found discussions of the Iowa species with reports of some experimental studies in control. However, so many points remained undetermined and there seemed so much need of a general survey of the conditions for the country at large that it was a special gratification to have the matter taken up by the Bureau of Entomology and to be given the opportunity of devoting some time to the study. Coming at a time when the Ohio State University authorities had generously offered a year's freedom from teaching, it has been possible for me to visit many different States and to examine field conditions, collections, etc., and in this way to obtain a comprehensive view of the situation that would have been entirely impossible under other conditions, and which has brought to light some measures of control that it is hoped will be of distinct service.

This field survey has included, in the summer and autumn of 1909, trips through the northwestern wheat-growing and grazing sections of Minnesota, the Dakotas, Montana, Wyoming, Idaho, and Washington; parts of Ohio, Indiana, and Illinois; and Iowa, New York, Pennsylvania, Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Tennessee, and Kentucky; and in 1910, Mississippi, Texas, Arizona, southern California, Utah, Colorado, Kansas, Iowa, Ohio, and Michigan, particularly the vicinity of Sault Ste. Marie.

SCOPE OF THE PRESENT INVESTIGATION.

The effort in this present work is to determine so far as possible the actual nature and extent of injuries to these crops by leafhoppers and the extent to which they form an economic factor, and to determine the conditions which affect their increase and destructiveness, the natural agencies which serve to keep them in check, and the possible basis for control by management of crops or application of direct remedies. The plan has been to make careful examinations of fields in the different regions visited, securing data so far as possible concerning previous history of fields or relation to preceding crops and to crops on adjacent fields, and to make extensive collections of specimens to determine the actual species present and the relative importance of these species to the crops concerned.

[1] Bul. 22, o. s., Div. Ent., U. S. Dept. Agr., pp. 26–32, 1890.

NATURE AND EXTENT OF INJURY.

Like other members of the order of Hemiptera, such as the squash bug, the chinch bug, aphides, scale insects, etc., the leafhoppers secure their food and incidentally occasion injury to the plants they infest by sucking the juice of the plant. The mouthparts consist of a beak or proboscis, inclosing slender threadlike piercing organs which are thrust into the plant and through which the plant juices are drawn into the stomach. The result is a wilting or shriveling of the plant cells that are thus depleted of their contents, sometimes a curling of the leaf or the distortion of the adjacent parts, and in some cases a discoloration of the surface. This sometimes becomes a factor in protecting the insect, especially when the color of the insect and that of the plant cells is the same. Probably the most familiar examples of this kind of work are those of the wilting noticed following attacks of the squash bug or the chinch bug, the whitening of grapevine leaves by the grape leafhopper, or the coloring and curling of leaves infested by plant-lice.

On grasses and grains the attack is most commonly noticed in the form of wilted or discolored blotches on the leaves or stems. It was described by Webster as a combination of punctures and slitting. Sometimes, in bluegrass particularly, it results, as the writer believes, in the condition known as "silver top," a whitening of the entire upper part of stem and head, though this particular condition is in some parts of the country undoubtedly due to attacks of the grass thrips (*Thrips striatus* Osb.)[1].

Another relation to be noted is connected with the parasitic fungi that are frequently associated with the leafhoppers. It seems quite possible that these fungi may be assisted by the leafhoppers in their distribution or entrance to the plant tissues. In work on the sugar-cane leafhopper in Hawaii the insect is credited with increasing attacks of the fungus.[2]

The author was informed by the plant pathologist connected with the Bureau of Plant Industry, United States Department of Agriculture, however, that while certain saprophytic forms might attack the injured spots punctured by the leafhoppers, the truly parasitic species like the rusts invariably attack the healthy tissue in preference to injured places; the leafhoppers might, however, easily be an agent in the scattering of the spores over the plant and hence become a factor in the increase of injury from rust. It is often a matter of much diffi-

[1] See article "Silver top in grass and the insects which produce it." Osborn, Can. Ent., vol. 23, pp. 93–96, 1891.

[2] See "Fungus Maladies of Sugar Cane," by N. A. Cobb. Exp. Sta. Hawaiian Sugar Planters' Assn., Bul. 5, Div. Path. and Phys. Also "Rind Disease of Sugar Cane." Bul. 7, Hawaiian Sugar Planters' Assn. A similar condition is presented in the fungus rice blast, which, according to Mr. H. R. Fulton (La. Exp. Sta., Bul. 105, Apr., 1908), gains entrance to the plant tissue through punctures of *Œbalus pugnax* Fab.

culty to distinguish in deadened spots on the leaves whether the primary cause was insect or fungus.

Still another phase of injury is to be noted in the effect produced upon a seed crop by the attacks of leafhoppers on the blossom or the newly forming seed. Puncture of the unfertilized blossom will easily make the pollination useless, as will also the suction of a small portion of the sap from a newly set seed cause it to wither or prevent its maturity. Injuries of this sort in wheat, timothy, clover, alfalfa, etc., are probably of much greater frequency than we are aware.

Whatever view we may take as to the extent of damage and relative importance of these insects, all who have studied the subject will agree that the puncturing of the tissue and pumping of the plant juices must result in more or less loss and drain on the plant. The importance then will rest on the abundance of the insects that may attack any particular plant. It is evident that an insect which simply pumps away the juices of the plant may go on with this operation, constantly draining the plant and reducing its rate of growth. Still, unless passing the point where the drain begins to cause actual wilting, withering, or unhealthy condition, it may attract no attention from the cultivator. Nevertheless, this drain must show in reduction of crop, less available pasturage or forage, and actual loss none the less real because difficult to estimate in dollars and cents.

In some estimates based on the abundance of insects actually collected in given areas I have claimed that from 25 to 50 per cent of the growth of grass may go to feed these leafhoppers and still all this loss may occur without meadow or pasture actually showing by wilted or withered plants that such a drain was occurring. Only in periods of drought and when this loss may commonly be charged against a dry season is the effect such as to be noticeable in meadows and pastures.

Some idea of the number of these insects can be gained from various observations and counts and some appreciation of it by walking through a pasture or meadow and noticing the clouds of minute leafhoppers that spring into the air in one's pathway. Estimates based on various captures in Iowa resulted in from a half million to a million insects per acre. In tests of the hopperdozer in catching them, the writer secured in some instances more than a million per acre, and obviously this number must fall short of what were actually present. Some careful estimates based on actual captures over plats 5 yards square were made at my suggestion in the autumn of 1908 by Mr. V. L. Wildermuth, now an assistant in the Bureau of Entomology. These were in timothy and bluegrass-timothy pastures, and while it can not be assumed that all the leafhoppers occurring in the given area were caught, the average for all these captures gives us a result of about a million per acre. The detailed statement of catches and

proportion of different species is shown in the following table, kindly furnished for my use by Mr. Wildermuth:

Record of leafhopper sweepings in the fall of 1908, by V. L. Wildermuth.

Date.	Number per 5 square yards.	Number per acre.	Other species.	Deltocephalus inimicus.	Dræculacephala mollipes—mostly.	Dicraneura.	Chlorotettix.	Athysanus.	Phlepsius.	Cicadula.	Platymetopius.
Oct. 3:[1]											
First record	352	1,022,288	6	200	75	10	8	7	40	0	6
Second record	285	727,640	13	125	80	25	4	10	15	3	10
Average of two counts	318	874,964	10	163	78	18	6	8	28	1½	8
Oct. 13:[2]											
First record	370	1,174,480	10	200	50	30	15	20	30	5	10
Second record	571	1,658,184	10	385	30	35	20	18	40	8	25
Average of two counts	471	1,416,332	10	292	40	33	17	19	35	6	18
Oct. 18:[3]											
First record	748	2,172,192	15	596	2	74	0	2	19	36	4
Second record	538	1,562,352	10	425	5	50	0	3	25	20	0
Third record	653	1,896,312	20	500	1	100	0	5	15	10	2
Average of three counts	646	1,876,952	15	507	3	75	0	3	19	22	2
Oct. 25 (cool day):[4]											
First record	354	1,028,016	25	300	0	20	0	0	8	0	1
Second record	418	1,213,872	10	356	2	45	1	0	0	0	4
Third record	303	879,912	30	250	0	10	0	3	6	2	2
Average of three counts	358	1,040,600	22	302	1	25	⅓	1	5	⅔	2

[1] Lowland timothy, fairly short.
[2] Timothy and bluegrass, Ohio State University Farm.
[3] Upland timothy, grass eaten short.
[4] Upland timothy, grass fairly short.

CROPS AFFECTED.

While our survey is intended to cover the various cereals and forage crops, it must for a number of reasons be more complete for those that are of most general culture. In general, it may be stated that all of the crops belonging to the grass family and most of those in general cultivation belonging to the legumes are infested by one or another, often by many, species of the leafhoppers. The abundance and corresponding injury vary greatly with these crops for different parts of the country and under different cultural conditions, as also with different seasons, so much so that general statements for annual crops are hardly applicable here. One of the most obvious conditions, however, is that the greatest drain occurs where, owing to continuity of crops or by close association of common food plants, there is offered an exceptional opportunity for the survival and increase of the insects from generation to generation through a season or during a series of years.

For the wheat, oats, rye, and barley crops the most important species are, in the North and Northwest, *Cicadula 6-notata* and *Athysanus exitiosus*, and in the South, *A. exitiosus* and *Dræculacephala*

reticulata. For the grass crop, including timothy, brome grass, and bluegrass, the most important species are *Deltocephalus inimicus*, *D. affinis*, *D. configuratus*, *Dræculacephala mollipes*, and *Phlepsius irroratus*. For clover, alsike, alfalfa, soy beans, and leguminous crops the most important are *Agallia sanguinolenta* and *Empoasca mali*.

The fact that in many parts of the country their injury is negligible for such crops as wheat, oats, rye, etc., is due to the rotation or alternation of crops in such manner as to make their rapid increase impossible. On the other hand, the conditions existing in permanent pastures and meadows or that prevail where wheat, oats, etc., are grown closely adjacent to considerable areas of permanent grassland furnish favorable opportunity for their multiplication and migration, and serious injury must inevitably follow. One of the strongest contrasts in this line is furnished by the methods of wheat culture in the North and South. Throughout most of the spring-wheat section of the Northwest and the winter-wheat section of the northeastern United States the complete system of rotation or the absence of adjacent grass areas at the time when wheat fields could be infested renders injury from these insects almost unknown. In a number of the Southern States, however, the abundance of the grasses adjacent or the overlapping of the seasons permits a serious autumn infestation of the fields of winter wheat, rye, and oats and a consequent annual loss from this source. This is especially true of the Piedmont Plateau in South Carolina and Georgia, where the prevailing practice of terracing (see Pl. II, fig. 3) to prevent washing of the hillsides results in permanent strips of uncultivated and permanent grassland, including a mixture of many kinds of useless weeds. Furthermore, the size of the fields must be an important factor in the extent of infestation from adjacent fields and consequent injury. Where the fields cover hundreds or thousands of acres, opportunity for infestation is far less than where they cover but a few acres and are interspersed with permanent grasslands.

In the extensive stock-grazing regions of the central-western and northwestern United States where there are extensive permanent pastures, and notably the great area of wild grazing land (see Pl. III, fig. 1), both prairie and woodland, these insects have the best opportunity for production of successive generations each season and their number is limited only by the ability of the plants to sustain them or by the control affected by natural enemies, such as the parasitic or predaceous insects, spiders, birds, etc., that feed upon them.

DERIVATION OF OUR LEAFHOPPER FAUNA.

Inasmuch as several economic problems are dependent on a knowledge of the source of our present leafhopper fauna, it is desirable that this matter should be touched upon, although it must be admitted

that we are far from having sufficient data to warrant very positive conclusions. Nevertheless, the known facts concerning a number of the genera or subfamilies seem to point in certain directions and a cursory review of these would seem in place. If we compare, in a very general survey, the American with European or Asiatic leafhopper groups, we are perhaps first struck with numerous fundamental similarities, and, second, with the comparatively few cases in which there seems to be specific identity; a condition which would indicate common origin for the groups in general, and, further, a common development through a long period with a separation only long enough to result in the minor separations of species. While migrations may account for some of the agreements, there are many in which such explanation seems unwarranted—and we have a few cases in which a comparatively recent introduction seems quite certain.

In the genus Deltocephalus, which is practically of world-wide distribution, a comparison two decades ago might have led one to believe the genus essentially European, as more than a half hundred species are listed there. But within the last 20 years species for North America have been discovered and described in large numbers until now there are nearly a hundred known from the United States alone, a number which far outweighs the European showing and, if judged by number of species, we will be obliged to consider America as the home of the group and postulate a distribution from here to other geographic regions. Certainly the immense variety of forms with their wide range in latitude and altitude must be accepted as evidence of great antiquity. A great many of the species are boreal or alpine in distribution and while perhaps some allowance should be made for more extended collection and study in the North, it appears evident that the center of abundance and of variety of adaptation is to be found in the plain and plateau region of the Mississippi Valley and among the Rocky Mountains. From such a center the species diminish in number to the southward, few being known from Central America and South America. Dispersal then may have proceeded by northward routes to Europe and Asia, and southward through Central America and into South America. As for the species which have a common distribution in America and Europe it is as easy to assume migration from America to Europe as the reverse. *Deltocephalus abdominalis* Fab. and *D. minki* Fieb., which occur in northern Europe and America, may thus have migrated in one direction or the other, but our *D. debilis* Uhl., which may be a derivative from *abdominalis*, has apparently had its origin in this country.

In rather striking contrast to the Deltocephalus group we may take the genus Agallia, which, with some 25 or 30 species for America, shows a strong preponderance both in number of species and adaptation for environment in the southern United States and especially

in Mexico, Central America, and the West Indies. If we note the bare half-dozen species known in Europe, and the further fact that nearly all the species drop off as we pass northward in either region, we can best incline to the belief that this genus is essentially tropical or at least subtropical in its origin and that its dispersal has been northward into the northern United States and Canada and probably by an African route into southern Europe. If such be the case, it is interesting to note that a separation into certain types within the genus must have occurred before the migration, as the European species *Agallia venosa* Fall. and *A. puncticeps* Germ. parallel very nicely our groups of which *Agallia sanguinolenta* and *A. 4-punctata* Prov. are typical examples. Such a derivation possesses peculiar significance in connection with certain habits and life-history features, especially in modes of hibernation, and some of these may prove of fundamental importance in connection with efforts toward practical control.

Again, we have in *Athysanus exitiosus* Uhl. a species which has in all probability spread over the United States in very recent times, possibly even within the last half century, and which almost certainly had its dispersal from a tropical or subtropical center.

Another similar case, discussed more fully in another place, is found in *Dræculacephala reticulata* Sign., which is even now probably working gradually northward, though it seems from its present distribution to have a pretty definite climatic restriction.

SPECIES PRINCIPALLY CONCERNED IN DESTRUCTIVE ATTACKS.

Serious outbreaks upon different cereal crops are to be charged to a few species, notably *Deltocephalus inimicus, D. nigrifrons, Cicadula 6-notata, Dræculacephala reticulata, D. mollipes, Athysanus exitiosus,* and *Phlepsius irroratus,* all of which are among the most important from an economic point of view. There are numerous other species which attack these crops, especially various grasses and forage crops, the habits of which are important, but whose injuries individually are of less consequence than for the species just cited. In the case of the wheat crop serious attacks in America are to be charged against the few species above mentioned, all of which, except one, are native to this country; hence, not original wheat-feeding species. They seem, however, to find this plant an attractive food and where conditions permit will gather upon it in very destructive numbers and cause serious injury. Comparatively speaking, very few of the old-world species in this group have followed the wheat plant to this country, and there is only one species common to both Europe and America that can be considered a pest. Whether this species has been introduced since the introduction of wheat in this country is a question that probably can not be determined, since it is now so widely distributed that there is little evi-

dence pointing to the trend of its distribution. (See discussion under *Cicadula 6-notata*, pp. 97–99.)

It is extremely probable that some of the native species that occur in moderate numbers on various native plants have been stimulated by the introduction of cultivated crops which have furnished them a fresh food supply, so that they have increased greatly in numbers and have become of more importance from an economic standpoint than would have been true in their connection with native plants. Most of our species, especially those that attack cultivated crops, have a wide range of food plants. Some, however, are restricted very closely to certain genera or species of plants as hosts.

GENERAL HABITS.

There are several features in the general habits of these insects which may be discussed together, although there are certain ones in which each particular species must be considered by itself. In their food habits, as has been mentioned, there is a wide diversity, some species affecting a great variety of plants, others a very few. The various species, however, agree pretty generally in attacking the leaves or the freshly grown portions of the stem of the plant, making their punctures where they can secure the sap with the greatest ease, thus affecting the growth of the more succulent portions. In many instances the insect shows a distinct adaptation to certain parts of the plant, so that the shape and color of the body blends in with the part upon which it is feeding. This is the most noticeable in the case of certain species which are marked so that the colors blend with certain portions of the plant, notably in cases where this coincides with the markings at the joints of the stems, instances being known where such blending causes the most perfect resemblance of the insect to the joint. Some of the insects affect the seeds or blossoms, others cluster near the ground, and some have even been reported as affecting the roots, but this must be exceptional as very few have been noted to attack the plant in this manner. There is no distinct adherence to a particular plant except during the nymphal stages or for certain species which have aborted wings and are therefore unable to fly; practically all the species, however, jump with great facility and if disturbed will leave the plant and come to rest either on the ground or some adjacent plant.

General migration of the insects is not common, but there must be local migrations from field to field, especially at times when the food supply becomes scarce or unsuitable on account of the ripening of the plant. At such times we may have a general dispersal of the insects; for instance, from wheat fields to adjacent grasslands, or in autumn from grasslands to adjacent fields of fall wheat, oats, rye, etc., which furnish a much more attractive food for that season. Migrations in

any wide sense are unknown for any of the species. There has been observed in many cases a distinct tendency to gather at night around conspicuous lights, and while it is not known whether all of the species are thus attracted, so many different ones have been noted as being attracted by artificial lights that we may fairly presume that the habit is quite general. An instance was reported to the writer by Prof. Stedman, formerly of Missouri, with accompanying specimens of *Dræculacephala mollipes*, to the effect that this species gathered about lights at Columbia, Mo., in such numbers that they could be gathered up by the bushel. We have noted many instances of the appearance of the various species, including practically all of the more common, in rooms which are brilliantly lighted. This habit is sufficiently pronounced that it may be utilized for the purpose of collecting and destroying the adults before they have deposited eggs, although it has not been experimented upon to such an extent as to warrant any conclusion.

An interesting case of the assembling of these insects at Urbana, Ill., has been reported to me by my son, H. T. Osborn. He states that on the evenings of October 9 and 10, 1909, he noticed a cloud of insects about a cottonwood tree and upon examination found that these consisted largely of the *Phlepsius irroratus*. These were so numerous that he caught a net full, but no evidence of egg-depositing or of a particular object in this assembling was noticed.

The winter condition of these species varies, some of them passing the colder months as adults and in these egg-laying occurs in early spring; others hibernate as partially grown nymphs; and in other species, particularly the grass-infesting forms, hibernation is apparently common in the egg stage. This matter of hibernation is of the greatest importance, especially in connection with methods of control based on the treatment that is possible in late autumn and in early spring. It also is related to the effects of climate, as in the case of those forms which become active in mild weather during winter and are thus exposed to conditions which may affect their survival and the consequent injuries the following season. Another general habit which is of importance is a tendency to dispersal from one kind of plant to another during the last nymphal stage. It has been noticed that many species which seem to be very closely restricted to particular plants in the earlier nymphal stages, during the last nymphal stage scatter freely to different kinds of plants, showing a distinct disposition to vary their diet.

LIFE HISTORY IN GENERAL.

All of the species of leafhoppers pass through a series of molts, usually four or five in number, and in these various stages they show a gradual progression toward the adult form. In some cases these

early forms are sufficiently like the later and adult stages to be recognized, but more commonly there is sufficient difference in their appearance so that it is only by rearing them from stage to stage or by careful comparison of the different stages that it is possible to make out the correct life history. All, of course, pass through the egg and larval stages, and the last nymphal stage may be considered as corresponding to the pupal stage of insects in general. So far as has been determined the eggs in the species affecting grains and grasses are deposited in the leaves or stems of the food plants of the larvæ. The method of deposition has not been accurately noted in very many instances, but, for such as have been observed, it consists in the pushing of the eggs by means of the strong ovipositor into the margin of the leaf or into the spaces between the leaf and the stem so that the eggs are protected either by a covering of epidermis or by the thin leaf-sheath surrounding the stem. A good example of the method of egg deposition is found in the case of the shovel-nosed leafhopper, which is figured on page 66. The number of eggs deposited by an individual is known in a few cases and probably varies with different species. In some cases it must be considerable, as the rate of multiplication is rapid. The hatching of the eggs takes place either in a few days after the deposition or, in the case of hibernating eggs, early in the following spring, and consists simply in the emergence of the larvæ, the eggs being broken open at the end nearest the opening into which the egg has been forced. The molting occurs at uniform periods and consists in the shedding of the entire epidermal covering, this usually remaining attached to the surface of the plant as a thin, transparent film. The insects increase in size and soon change from the light color of recent emergence to the dark intense color common to the species. The number of generations in each season is also a variable matter, but there are commonly two generations each season, in some probably three, and in a few it is known that a single generation occurs. This is, of course, an important factor in the economic importance of the species since each additional generation provides for an immense increase of the numbers of individuals and also makes the special conditions of culture for the crop on which it feeds much less effective.

ECOLOGIC RELATIONS.

The leafhoppers constitute one element in a very complex relation of plants and animals, including birds, mammals, reptiles, toads, insects, spiders, etc., and it is only by the recognition of this relation that we can offer any very adequate explanation of their proper place in nature, and of their importance in the economy of cultivation. Primarily they are associated with certain kinds of plants upon which they depend for their sustenance, and the abundance of leafhoppers will be affected, necessarily, by the abundance of the food plant and

its availability as food material. An undue increase of the leafhoppers, which should result in the diminution of the food supply, must necessarily affect the possibilities of multiplication and cause a certain reduction in the number of the insects. This is, however, by no means the only statement of conditions as, aside from these two forms which may be associated in the same area, a large number of other organisms, both plant and animal, will affect the problem. The occurrence of different birds and predaceous insects which prey upon the leafhoppers will naturally reduce their numbers and to that extent favor the plants which serve as their food, whereas the presence of herbivorous animals, grasshoppers, cutworms, etc., serves to reduce the available food supply. Aside from these dominant forms there are also various fungus parasites which attack both insects and plants and which play their part in the complex of which the leafhoppers are such a conspicuous element. Furthermore the minute insect parasites which attack the leafhoppers add their part, tending to keep the latter reduced in numbers. The relation of these and other direct parasites which concern them may be considered under the general head of natural enemies.

NATURAL ENEMIES.

That leafhoppers maintain a fairly average abundance from year to year, for the most part causing no perceptible devastation, is due to the fact that there are so many different natural agencies tending to reduce their numbers or to keep them in check. Of these natural enemies birds, spiders, and predaceous and parasitic insects are probably the most important and require careful consideration.

It seems improbable that leafhoppers are affected to any great extent by mammals, except as eggs may be swallowed by foraging species—cattle, sheep, etc. The only forms which would seem likely to feed upon them are the moles and these confine their work so largely beneath the surface of the ground that it is doubtful if they would secure many of the leafhoppers. There are no records to show any service in this direction.

Birds.

Birds would undoubtedly be thought of as an important factor in the natural control of leafhoppers. It would seem that they might feed very commonly upon these insects; and yet very little has been published in the way of correct determination or definite records of the kinds of birds which feed upon them, or the extent to which these leafhoppers enter into their normal food. The most complete records in this line are those accumulated by the Bureau of Biological Survey of the Department of Agriculture, which has for many years past been making a record of the contents of birds' stomachs. Besides the

published data concerning certain species of birds, that bureau has an immense collection of unpublished records and these have been very kindly put at my disposal for the purpose of this study. Practically all of the data here presented on this point were derived from this material. While these records do not, in most cases, give the particular kind of leafhopper which is fed upon by certain species of birds, it should represent, of course, the kinds of leafhoppers which were abundant at the time and place indicated. The birds, of course, make no discrimination between species, except as they might appear in numbers or prove an easier prey.

EVIDENCE AS TO THE RELATION OF BIRDS TO LEAFHOPPERS.

While at first thought we might consider birds as a most important element in control of these insects, a closer study reveals many reasons why they must depend upon them but little as a food supply. Even with this more conservative view in mind, however, the actual condition as represented by the records of the Biological Survey are rather disappointing since they show that for practically all of our common birds the leafhoppers constitute so small a portion of their food supply that birds very properly may be considered as almost negligible in any consideration of the natural agencies of control. It is, however, important, both as a matter of record and for the benefit of future workers, that the actual condition as indicated by these records should be made available, and I have endeavored to sum up, as briefly as possible, the results of an analysis of the figures obtained, and the table of records is appended.

According to the records consulted by me and later revised by the Biological Survey, there are 119 different species of birds among those examined by that bureau whose stomachs contained jassid remains in various proportions, from a trace to 80 per cent. But, putting all the stomachs together, we have only 770 which contained jassid material out of a total of some 47,000 stomachs examined, or less than one out of fifty.

Even for the species of birds showing jassids in their food, we have only 770 out of about 28,000 (about 1 in 40) stomachs which included jassid remains and for a large majority of these stomachs examined the jassid contents were but from 1 to 10 per cent, so that on a most liberal estimate we can claim about the thousandth part of the food of birds as being made up of leafhoppers.

However, this general average may not represent the actual condition of effectiveness, for some of our most common birds abound in pastures and meadows where leafhoppers occur, and a critical examination for such species is desirable.

In the first place we may eliminate practically all the waterfowl—loons, divers, gulls, terns, pelicans, ducks, geese, cranes, bitterns,

herons, etc.—since they usually frequent places where these insects are not abundant.

A few records occur for snipe and sandpiper and one for the spotted sandpiper indicating that this latter bird may feed quite extensively on leafhoppers—probably species occurring on grasses in marshy ground.

Of the grouse family, the habits of which would seem to make them fitted to secure some portion of jassid food, only a very few records show such diet. Out of 75 prairie chickens, now no longer a factor except for the plains region, only one had eaten jassids; but the one taken on a Nebraska prairie in October had jassid material for 40 per cent of its stomach contents. This would show distinct ability to feed on these insects when available. For the common quail or bobwhite, whose wide distribution and frequent abundance make it perhaps of greater interest for this family, out of 971 stomachs only 35 contained jassid fragments, and for these they constituted only a very small percentage of the food, usually from 1 to 7 per cent. What the quail might do, however, in the case of an abundance of material of the larger species is shown in a series of stomachs from Virginia, taken in autumn, which included numbers of *Oncometopia lateralis*.

For the partridge (*Bonasa umbellus*), one bird out of 423 had eaten one leafhopper (a tettigonid) or 1 per cent—a food ratio for the species of 1 to 42,300, but so far as open fields are concerned this bird is naturally not to be considered of importance.

We would not expect the larger birds of prey, hawks, owls, etc., to feed at all on such small insects, so it may be considered merely accidental that the Cooper's hawk, one bird out of 109, had eaten a froghopper (a cercopid), which constituted one-twentieth of its stomach contents. Possibly, too, this was contained in the stomach of some other animal eaten by the hawk and, being less easily disintegrated in the process of digestion, remained as a fragment in the stomach.

The woodpeckers certainly would not be expected to prey on these insects, and for only one species, the downy woodpecker (*Dryobates pubescens*), is there any record, and that for only two birds out of 750.

Stomachs of Allen's humming bird, of the Pacific coast, show a record of 1 in 3 with 22 per cent jassid food; but this is offset by 88 per cent of spiders, which would suggest that the jassids were secured when in the grasp of spiders; another western hummer, *Calypte anna*, shows 10 in 111.

The nighthawk is distinctly insectivorous and as jassids are more or less on the wing at night these would seem open to attack, but the record shows only 22 birds out of 250 to have fed on them and the ratio of these to other insects to be very small. One or two exceptional cases would indicate captures during some extensive flight of jassids.

The chimney swift, a distinctly insectivorous bird, shows 13 out of 139 to have eaten leafhoppers, but one of these showed 50 per cent jassid material.

The flycatchers, which are preeminently insect feeders and active in the meadows and pastures, show, nevertheless, a very small leafhopper diet. The best record is for a California species (*Empidonax difficilis*) for which 11 birds in a total of 148 had eaten leafhoppers and in proportions as high as 73 per cent. Among our eastern species, only 3 birds in 91 of the yellow-bellied flycatcher (*Empidonax flaviventris*) had eaten leafhoppers, and in the proportion of 3 to 15 per cent.

Traill's flycatcher (*Empidonax trailli*) shows 5 in 134 with proportion for these up to 10 per cent, the Acadian flycatcher (*E. virescens*), 3 in 93 with 10 per cent for two, and least flycatcher (*E. minimus*), 4 in 162 with 10 per cent of jassid material in two and 20 per cent in one. The record for these four eastern flycatchers which might be expected to be especially serviceable shows, therefore, all together only 15 out of 480 stomachs to include jassid material, and the average for these can not be estimated as more than 10 per cent, so that the ratio of jassid diet would be only 1 to 500, or one-fifth of 1 per cent. The best that can be claimed for them, therefore, is that in case of excessive numbers of leafhoppers they might help a little in their destruction.

Even less useful in this connection are the phoebe and pewee, showing only about 2 to 100 with jassid contents, though two stomachs contained, one, 88 per cent, and another 100 per cent. The common kingbird, so universally present in fields, shows still less, 6 in 634, one bird, however, showing 52 per cent.

One of the best showings is made by a California species, *Myiarchus cinerascens*, for which 7 out of 90 birds had eaten jassids and in proportions as high as 94 per cent, while the eastern crested flycatcher (*Myiarchus crinitus*) shows again only 3 in 244 and a proportion of 5, 15, and 50 per cent.

Among the family of orioles and blackbirds, the cowbird shows the best record as a jassid feeder, there being 25 stomachs out of 590 with jassid contents, and for these 25 the proportion varies from a trace to 61 per cent, the average percentage for the 25 stomachs being 18.5 per cent—a food ratio of approximately 1 to 128; that is to say, 1 bird out of every 23 had eaten jassids to the extent of nearly one-fifth of his bill of fare. It is fair to assume that many of the birds showing no jassid diet were taken at times or places where this food was not available, and on this basis we can fairly credit the cowbird with good service—the best apparently of any of the birds for which data have been examined except the sharp-tailed sparrow.

The California redwing (*Agelaius gubernator*) shows a quite excellent record of 12 to 200, but our eastern species (*Agelaius phœniceus*)

only 7 in 1,150; the purple grackle or crow blackbird (*Quiscalus quiscula*) only 10 in 2,384, and these either but a trace or very small percentage, and the common meadowlark, a most familiar field resident, shows no record at all of eating Jassidæ, but two birds out of 1,157 had eaten cercopids to the extent of 5 per cent and 2 per cent. The Baltimore oriole (*Icterus galbula*) gives 1 in 207, but this one contained 88 per cent jassids. The orchard oriole (*Icterus spurius*) 3 in 153, and the Bullock's oriole (*Icterus bullocki*) 6 in 293.

In the sparrow family there are many species which from constant occurrence in fields have a distinct interest in this connection. While primarily seed feeding, it is known that many of them frequently include insects in their diet. None of the stomachs, however, except possibly the sharp-tailed sparrow, shows a sufficient amount of jassids to indicate that the members of this family are of any consequence as a check for these pests.

The lark sparrow shows only 5 in 257 and very small percentages in these five; the sharp-tailed sparrow 4 in 44, and *Passerherbulus maritimus* 2 in 31; the swamp sparrow, 2 in 72; the Lincoln sparrow, 4 in 42, and the common song sparrow, 12 in 714; the savanna sparrow, 3 in 300; the spotted bunting (*Pipilo m. montanus*) 2 in 150; the vesper sparrow, 2 in 140; the field sparrow 4 in 240, and the tree sparrow 2 in 555. The field sparrow shows 4 in 250, but these four are high, two being credited with 100 per cent jassids.

The sharp-tailed sparrow, with 4 birds out of 44, shows percentages of 80, 80, 75, and 30, or an average for the four of 66⅔ per cent, or a ratio for the 44 birds of 1 to 17, or 6 per cent jassid food, which is the highest percentage we have noted for any species and shows no records of spiders eaten.

The next best of these records, 4 in 42 or 1 in every 10½ for the Lincoln sparrow, with percentages of 4, 15, and 24, applies to one of the less common birds, and when the proportion of jassid material is noted gives us only 1 to 100 as the real ratio of leafhopper food to be credited to this bird.

Two of the swallows, the violet-green swallow and the bank swallow, show considerable numbers, but these are doubtless from cases of unusual flight. The good record of the marsh wren is offset by the fact that it must be of little service except in swampy places, but the Bewick wren, if a more common bird, would make a very good showing.

One of the nuthatches, *Sitta pygmæa*, as will be seen by the table, has a very striking record of 18 stomachs out of 32 birds with several containing 100 per cent of cercopids, but this is a Pacific Coast species and the tree-feeding habits of the bird exclude it from any probable service in grass or grain fields.

It is clear, if any conclusions at all are warranted from the mass of evidence here available, that it is useless to depend on birds for

control of these insects. No amount of "encouragement for the birds" or efforts to utilize their service in this direction can be expected to have any appreciable effect in reducing the number of leafhoppers, and we may dismiss this idea and turn our attention to other more hopeful agencies.

It should be kept in mind distinctly that these conclusions refer only to the relation of birds to this particular class of insects and must not be used as an argument for or against the status of birds in relation to the control of insects in general or of any other group of pests. The writer is fully aware of the important service that is rendered by many of our common birds in the control of a number of serious insect pests and would by no means wish to contribute to any undervaluation of their service.

The following list, with the leafhopper species arranged in alphabetic order, shows the species of birds which have fed upon leafhoppers, the number of stomachs containing such material, with the total number of stomachs examined for each species and the percentage for each record, as very kindly revised and corrected up to January 1, 1912, by the Biological Survey.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families.

FULGORIDÆ.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Chætura pelagica	Fulgoridæ	137	2	1, 1.
Chordeiles virginianus	do	266	4	2, trace, 1, 1.
Otocoris alpestris	do	1,159	1	9.
Pyrrhuloxia s. texana	do	74	1	5.
Chordeiles virginianus	Oliarus aridus	[1]	1	12 (12 spm.).
Colinus virginianus	Scolops maculosus	971	1	2.
Lophortyx californicus	Scolops sp	619	1	10.

CERCOPIDÆ.

Accipiter cooperi	Cercopidæ	100	1	Trace.
Chamæa fasciata	do	170	1	12.
Geothlypis trichas	do	130	1	30.
Iridoprocne bicolor	do	164	1	10.
Melospiza melodia	Cercopidæ (1 with 5 spm.)	718	3	15, 5, 100.
Otocoris alpestris	Cercopidæ	[1]	2	12, 20.
Quiscalus quiscula	do	2,384	1	2.
Sturnella magna	do	1,157	2	5, 2.
Penthestes atricapillus	do	644	3	50, 79, 90.
Polioptila cærulea	do	39	2	30, 20.
Setophaga ruticilla	do	17	2	81, 50.
Sitta pygmæa	do	32	18	100, 88, 100, 20, 79, 83, 90, 100, 77, 25, 50, 72, 45, 100, 100, 100, 85, 65.
Thryomanes bewicki	do	153	1	6.
Chordeiles virginianus	Aphrophora sp	[1]	1	Trace.
Chordeiles virginianus	Clastoptera xanthocephala (12 specimens.)	[1]	2	Trace, 1.
Junco aikeni	Ptyelus sp	1	1	40.

[1] Number of stomachs recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

TETTIGONIDÆ.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Hylocichla guttata	Tettigonidæ	460	2	70, 5.
Bonasa umbellus	do	423	1	Trace.
Cardinalis cardinalis	do	496	2	50, 12.
Myiarchus crinitus	do	244	1	15.
Sayornis phœbe	do	353	6	7, 25, 15, 6, 30, 25.
Muscivora forficata	Aulacizes irrorata	128	1	30.
Chordeiles virginianus	Dræculacephala reticulata	(1)	1	9.
Colinus virginianus	Diedrocephala sp	(1)	4	1, 1, 1, 4.
Telmatodytes palustris	do	59	1	2.
Chætura pelagica	Diedrocephala versuta	(1)	1	1.
Chordeiles virginianus	Dræculacephala mollipes	(1)	5	6, 10, 8, 1, 8.
Chordeiles virginianus	Dræculacephala reticulata	(1)	1	9.
Chætura pelagica	Dræculacephala sp	(1)	2	1, 10.
Chordeiles virginianus	do	(1)	2	40, trace.
Chordeiles virginianus	Gypona octolineata	(1)	1	Trace.
Chordeiles virginianus	Gypona sp. (1 with 12 spm.)	(1)	2	2, trace.
Pediœcetes phasianellus	Helochara communis	52	1	5.
Colinus virginianus	Homalodisca coagulata	(1)	1	5.
Colinus virginianus	Oncometopia lateralis	(1)	11	Trace, 6, 1, 5, 3, 2, 2, 4, 5, 1, 3.
Pediœcetes phasianellus	Oncometopia lateralis (20 spm.)	(1)	1	5.
Sayornis phœbe	Oncometopia lateralis	(1)	2	61, 8.
Colinus virginianus	Oncometopia sp	(1)	14	5, 3, 3, 5, 1, trace, 3, 5, 5, 5, 1, 1, 1, 4.
Sayornis phœbe	Oncometopia undata	(1)	1	80.
Empidonax trailli	Tettigonia atropunctata	134	1	4.
Pediœcetes phasianellus	Tettigonia sp	(1)	1	3.
Chordeiles virginianus	Xerophlœa viridis	(1)	6	1, trace, 1, trace, trace, 1.
Planesticus migratorius	do	1,126	1	1.

BYTHOSCOPIDÆ.

Chætura pelagica	Agallia 4-punctata	(1)	4	1, 4, 4, 1.
Otocoris alpestris	Agallia sanguinolenta	(1)	2	6, 15.
Lobipes lobatus	do	66	1	80.
Chordeiles virginianus	Agallia sp	(1)	2	Trace in both.
Marila americana	do	67	1	Trace.

JASSIDÆ.

Actitis macularia	Jassidæ	3	1	5.
Æronautes melanoleucus	do	12	2	2, 2.
Agelaius gubernator	do	200	12	1, 1, 3, 1, 7, 1, 2, 2, 7, 15, 25, 2.
Agelaius phœniceus	do	1,150	7	5, 1, 1, 1, 2, 1, 1.
Aimophila ruficeps	do	25	1	66.
Passerherbulus caudacutus	Jassidæ (1 with 12 spm.)	44	4	80, 80, 30, 75.
Passerherbulus maritimus	Jassidæ	31	2	15, 20.
Anthus rubescens	do	36	2	20, 2.
Aphelocoma californica	do	626	2	3, 1.
Archilochus colubris	do	62	3	90, 35, 1.
Bartramia longicauda	Jassidæ (1 with 10 spm.)	160	2	5, 20.
Bæolophus bicolor	Jassidæ	74	1	35.
Bæolophus inornatus	do	76	1	10.
Calypte anna	do	111	10	50, 10, 60, 90, 90, 50, 94, 100, 50, 50.
Chætura pelagica	Jassidæ (1 with 50 and 1 with 40 spm.).	139	13	50, 1, 9, 1, 2, 3, 2, 2, 20, 3, 15.
Chætura vauxi	Jassidæ	3	2	3, 20.
Chamæa fasciata	do	170	9	2, 10, 10, 2, 20, 35, 1, 3, 60.
Chondestes grammacus	do	257	5	2, 5, 20, 1, 5.
Chordeiles a. texensis	do	17	2	10, 7.

[1] Number of stomachs recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

JASSIDÆ—Continued.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Chordeiles virginianus	Jassidæ	250	22	10, 1, 1, 46, 1, 1, 47, 20, 1, 1, 3, 1, 3, 43, 1, 6, 1, 56, 1, 5, 15, 5.
Colinus virginianus	do	971	15	1, 1, 1, 1, 1, 5, 1, 1, 2, 1, 1, 2, 1, 5, 3.
Myiochanes richardsonii	do	162	4	4, 10, 22, 5.
Myiochanes virens	do	359	4	25, 22, 24, 74.
Ammodramus s. australis	do	170	7	20, 10, 15, 10, 25, 50, 5.
Cyrtonyx montezumæ	do	25	3	1, 1, trace.
Dendroica æstiva	do	116	18	25, 3, 20, 37, 73, 86, 40, 15, 15, 10, 15, 25, 4, 3, 30, 35.
Dendroica auduboni	do	385	21	2, 61, 5, 10, 80, 15, 2, 4, 6, 10, 15, 5, 6, 5, 5, 1, 5, 15, 6, 40.
Dendroica coronata	do	33	1	10.
Dendroica magnolia	do	11	3	4, 41, 10.
Dendroica townsendi	do	31	2	8, 3.
Dolichonyx oryzivorus	do	302	5	35, 33, 3, 5, 8.
Dryobates pubescens	do	750	2	6, 5.
Dumetella carolinensis	do	287	2	25, 10.
Empidonax difficilis	do	148	11	15, 44, 38, 15, 40, 45, 5, 12, 73, 10, 4.
Empidonax flaviventris	do	91	3	15, 8, 3.
Empidonax hammondi	do	6	1	7.
Empidonax minimus	do	162	4	10, 3, 10, 20.
Empidonax traillii	do	134	5	8, 10, 10, 2, 10.
Empidonax virescens	do	93	3	10, 10, 1.
Euphagus carolinus	do	132	1	10.
Euphagus cyanocephalus	do	399	8	1, 1, 1, 3, 1, 1, 1, 3.
Gallinago delicata	Jassidæ (12 spm.)	145	1	50.
Geothlypis trichas	Jassidæ	130	13	20, 15, 5, 85, 15, 45, 30, 40, 15, 8, 2, 25, 50.
Vermivora celata	do	77	2	4, 81.
Vermivora peregrina	do	1	1	6.
Hirundo erythrogastra	Jassidæ (1 with 1,000 spm.)	331	23	1, 77, 1, 3, 20, 40, 5, 10, 4, 30, 48, 10, 4, 1, 1, 16, 10, 4, 3, 1, trace, 10, 7.
Hylocichla guttata	Jassidæ	(1)	6	16, 5, 1, 1, trace, 6.
Hylocichla mustelina	do	162	1	Trace.
Hylocichla ustulata	do	385	7	1, trace, 2, 2, 7, 5, 10.
Icterus bullocki	do	293	6	1, 6, 2, 8, 1, 5.
Icterus galbula	do	207	1	88.
Icterus spurius	do	153	3	1, 20, 10.
Iridoprocne bicolor	do	164	8	70, 3, 5, 6, 1, 2, 79, 35.
Junco hyemalis	do	553	11	75, 25, 35, 10, 20, 20, 20, 30, 5, 50, 30.
Lanivireo solitarius	do	47	10	80, 15, 15, 20, 10, 92, 20, 10, 20, trace.
Lophortyx californicus	do	619	6	1, 1, 2, 1, 1.
Mimus polyglottos	do	119	1	1.
Megaquiscalus major	do	121	2	Trace, trace.
Meleagris gallopavo	do	16	1	Trace.
Melospiza georgiana	do	72	2	65, 75.
Melospiza lincolni	do	41	3	25, 15, 4.
Melospiza melodia	do	718	12	10, 35, 70, 20, 1, 10, 25, 5, 50, 5, 6, trace.
Molothrus ater	do	590	25	2, 31, trace, 4, 15, 1, 28, 20, 1, 25, 61, 10, 29, 2, 4, 60, 8, trace, 1, 6, 7, trace, trace.
Muscivora forficata	do	127	1	6.
Myiarchus cinerascens	do	90	7	10, 10, 94, 7, 15, 30, 3.
Myiarchus crinitus	do	244	3	5, 50, 15.
Nannus h. pacificus	do	13	1	15.
Oporornis philadelphia	do	2	1	70.
Otocoris alpestris	do	1,159	14	30, 2, 8, 5, 60, 15, 40, 1, 20, 35, 12, 15, 5, 2.

[1] Number of stomachs recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

JASSIDÆ—Continued.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Passerculus sandwichensis	Jassidæ	300	3	35, 50, 15.
Penthestes atricapillus	do	344	3	20, 55, 6.
Penthestes carolinensis	do	82	1	2.
Penthestes gambeli	do	11	1	30.
Penthestes rufescens	do	61	4	11, 74, 47, 40.
Petrochelidon lunifrons	do	211	30	1, 1, 15, 83, 40, 10, 35, 15, 35, 1, 67, 15, 1, 6, 20, 2, 15, 20, 10, 15, 20, 15, 5, 5, 40, 6, 15, 40, 20.
Pipilo f. crissalis	do	400	9	1, 1, 1, 9, 43, 20, 4, 2, trace.
Pipilo maculatus	do	147	2	10, 1.
Planesticus migratorius	do	[1] 1,126	5	1, 1, 3, 1, 3.
Polioptila cærulea	do	39	6	40, 5, 65, 50, 30, 40.
Polioptila californica	do	31	9	75, 30, 20, 20, 30, 40, 40, 40, 50.
Pocœcetes gramineus	do	32	2	5, 3.
Psaltriparus minimus	do	354	8	44, 7, 2, 15, 45, 15, 75, 7.
Pyrrhuloxia s. texana	do	74	1	3.
Quiscalus quiscula	do	2,384	10	1, 20, 2, trace, 1, trace, 6, 14, 3.
Regulus calendula	do	300	47	88, 82, 1, 10, 25, 25, 50, 5, 93, 70, 25, 40, 25, 98, 30, 48, 82, 12, 98, 18, 15, 8, 15, 40, 20, 10, 5, 25, 50, 55, 25, 6, 65, 41, 45, 45, 25, 20, 54, 35, 43, 78, 25, 5, 25, 10, 20.
Regulus satrapa	do	9	1	50.
Riparia riparia	do	238	19	20, 94, 10, 15, 6, 5, 4, 40, 5, 1, 6, 30, 88, 2, 68, 46, 3, 5.
Sayornis nigricans	do	343	4	5, 1, 1, 40.
Sayornis phœbe	do	353	6	5, 25, 100, 88, 25, 10.
Sayornis sayus	do	110	3	2, 7, 40.
Selasphorus alleni	do	3	1	12.
Selasphorus rufus	do	61	2	80, trace.
Setophaga ruticilla	do	14	1	90.
Sialia currucoides	do	52	1	1.
Sialia m. occidentalis	do	215	2	1, 1.
Sialia sialis	do	745	1	2.
Spizella passerina	do	302	3	10, 23, 5.
Spizella monticola	do	555	2	1, 5.
Spizella pusilla	do	250	4	10, 50, 100, 100.
Stelgidopteryx serripennis	do	35	1	15.
Sturnus vulgaris	do	114	2	40, 1.
Tachycineta thalassina	do	80	25	40, 5, 45, 30, 3, 8, 5, 20, 15, 20, 40, 20, 15, 40, 89, 20, 10, 10, 15, 15, 25, 45, 15, 10, 50.
Telmatodytes palustris	do	59	9	20, 20, 100, 15, 35, 40, 25, 2, 12.
Thryomanes bewicki	do	152	17	40, 50, 1, 5, 63, 45, 10, 15, 97, 40, 20, 25, 10, 10, 4, 1, 25.
Lanius ludovicianus	do	210	1	100.
Troglodytes aëdon	do	108	4	5, 10, 1, 70.
Tympanuchus americanus	do	77	1	40.
Tyrannus tyrannus	do	634	6	15, 3, 3, 2, 10, 52.
Tyrannus verticalis	do	116	1	14.
Vireo griseus	do	14	1	65.
Vireo huttoni	do	58	6	50, 69, 15, 40, 3, 96.
Vireo belli	do	8	2	6, 15.
Vireosylva olivacea	do	28	2	20, 3.
Vireosylva gilva	do	114	7	35, 10, 40, 1, 30, 7, 10.

[1] Recorded elsewhere in this list.

Birds that have been found by stomach examination to have fed on leafhoppers; the latter grouped by families—Continued.

JASSIDÆ—Continued.

Name of bird.	Name of insect.	Total number of stomachs examined.	Number of stomachs containing insects of the family named.	Percentages.
Wilsonia pusilla	Jassidæ	67	11	67, 10, 50, 25, 33, 75, 15, 7, 60, 20, 15.
Xanthocephalus xanthocephalus	do	148	4	1, 1, 1, trace.
Zamelodia melanocephala	do	230	5	1, 4, 7, trace, 5.
Zonotrichia leucophrys	do	626	3	20, 15, 3.
Chordeiles virginianus	Acinoptera acuminata	(1)	1	2.
Chordeiles virginianus	Athysanus exitiosus	(1)	1	2.
Chætura pelagica	do	(1)	1	30 (12 spm.).
Chordeiles virginianus	Athysanus sp.	(1)	1	Trace.
Chordeiles virginianus	Cicadula 6-notata	(1)	1	Trace.
Agelaius phœniceus	Cicadula sp.	(1)	1	5.
Chordeiles virginianus	do	(1)	3	Trace, trace, trace.
Molothrus ater	do	(1)	11	4, 3, 10, 2, 1, 1, 10, 1, 8, trace, 5.
Psaltriparus minimus	do	(1)	2	20, 1.
Chætura pelagica	Deltocephalus flavicosta	(1)	1	2.
Chætura pelagica	Deltocephalus sp.	(1)	1	1.
Chordeiles virginianus	do	(1)	9	1, 12, 20, 5, 3, 8, 2, trace, trace.
Colinus virginianus	do	(1)	1	Not given.
Archilochus colubris	Empoasca sp.	(1)	1	55.
Chordeiles virginianus	Eutettix sp.	(1)	3	Trace in all.
Cyrtonyx montezumæ mearnsi	Phlepsius areolatus	24	1	1.
Chordeiles virginianus	Phlepsius cumulatus	(1)	1	1.
Chordeiles virginianus	Phlepsius excultus	(1)	1	1.
Chætura pelagica	Phlepsius irroratus	(1)	4	1, 1, 1, 8.
Chordeiles virginianus	do	(1)	8	10, 12, 2, 3, trace, trace, 1, trace.
Oxyechus vociferus	do	(1)	1	3.
Chordeiles virginianus	Phlepsius sp.	(1)	1	1.
Chordeiles virginianus	Thamnotettix lusoria	(1)	2	Trace in both.
Chordeiles virginianus	Thamnotettix sp	(1)	2	Trace, 1.
Dendroica tigrina	Typhlocyba sp.	(1)	1	8.
Vermivora peregrina	do	1	1	8.
Passer domesticus	do	421	2	100 per cent stomach nearly empty, 33.
Chordeiles virginianus	Xestocephala sp.	(1)	1	Trace.

TETTIGONIDÆ.

Larus franklini	Dræculacephala mollipes Dræculacephala mollipes var. minor. Tettigonia sp.	83	8	Trace in all.
		27,805	770	

[1] Number of stomachs recorded elsewhere in this list.

Reptiles and Batrachians.

The reptiles and batrachians are to be considered as a factor in the control of these insects, but there is little evidence of their being of much service, and except possibly for the frogs and toads, which are general insect feeders, there would seem to be little possibility of assistance from this group. Direct observations do not seem to show any evidence of the capture of leafhoppers by these animals, and in an elaborate record of the insects eaten by the common toad

given by Mr. A. H. Kirkland,[1] no record is given of leafhoppers having been eaten, but it is not stated whether the specimens examined came from meadows or grainfields where such insects were most likely to be taken. It is stated, however, that toads eat only active insects, and therefore they may not pay attention to the leafhoppers, which, except when disturbed, are very quiet. Moreover, as these animals feed mainly at night, the opportunity for them to capture leafhoppers would perhaps be much less than if they were feeding during the daytime. A special study of toads from meadows and pastures where leafhoppers are common would be an interesting addition to our knowledge in this line.

Insect Enemies.

The insect enemies for the leafhoppers are not so numerous as for some other groups of insects, but there are several which may be considered as of sufficient importance for notice.

Among the predaceous forms we have as the most abundant and efficient perhaps the little bugs of the family Nabidæ, some of which occur in great abundance in the meadows and pastures where the leafhoppers occur. The most abundant of the species is *Reduviolus ferus* L., which occurs throughout the entire range of the United States and may be found in almost every kind of grassy land. That it is a frequent predator upon the leafhoppers is indicated by its attack upon them when they are taken in the net, although it must be said that they are very seldom found with the insects actually impaled upon their beaks in the field. It is probable that this comes from their puncturing and sucking the blood of the insect very quickly and discarding the dead bodies so promptly as not to be found with them actually impaled. I have no question that they feed upon the leafhoppers as one source of their food supply, and believe them to be one of the principal agencies in keeping the leafhoppers in check.

Another group which is less notable is the genus Geocoris in the family Lygæidæ. These are minute flattish bugs with prominent eyes, and they occur as widely distributed common insects on the ground among the grasses and other low-growing vegetation. Their attack upon leafhoppers has been reported to me by various observers, and during the season of 1910 a definite record was furnished by Herbert T. Osborn of the Bureau of Entomology, for the species *Geocoris decoratus* Uhl. This, he states, was found at Wellington, Kans., in a number of instances with small leafhoppers impaled on its beak, and numbers of dead leafhoppers were found in the vicinity. The specimens submitted were *Empoasca flavescens* Fab. As this species of Geocoris is common over a wide range, it is doubtless serviceable in this manner in connection with many other species of leafhoppers.

[1] Bul. 46, Mass. Hatch Experiment Station, 1897.

The related species, especially *bullatus* Say, *uliginosus* Say, and *borealis* Dall, which are equally common over most of the country, certainly must contribute largely toward the reduction of the leafhopper pest.

PARASITIC INSECTS.

We have, in the parasitic insects affecting the members of this group, another most constant means of control, and one which is perhaps far more important than we readily appreciate. Among these forms are numbers of Hymenoptera, Diptera, and Strepsiptera. Of the Hymenoptera the most abundant parasites are included in the families Proctotrypidæ and Dryinidæ in the genera Gonatopus and Dryinus. These parasites affect the larvæ more particularly, but are often found upon the adults and are conspicuous, inasmuch as for many of the species the parasitism takes the form of an external sack-like structure in which the larva develops on material sucked from the body of the host. In some of our native species these parasites have been found present in something like 20 per cent of the individuals, so that it is evident that they must constitute a quite distinct check upon the leafhoppers. An extensive series of records showing the parasitism of these forms is found in the reports of the Hawaiian entomologist and in the papers of Perkins and others in connection with investigation of leafhoppers affecting sugar cane. Many species were collected and reared from leafhoppers occurring in the United States for the purpose of introducing them into the Hawaiian Islands in hopes that they might prove of service in control of the sugar-cane leafhopper (*Perkinsiella saccharicida* Kirkaldy). A detailed account of these species would hardly be in place here, but the importance of this source of control is sufficient to make it worthy of further investigation.

Among the Diptera a genus, Pipunculus, is recorded as parasitic upon leafhoppers, and Giard is authority for the opinion that these are in general parasites, especially of the family Jassidæ. These have not been recognized to any great extent in this country, and we are unable to say to what extent they may have a service here.

The order Strepsiptera, or the twisted-winged insects, includes some very peculiar and remarkable parasites, numbers of which have been recognized as occurring on leafhoppers. These parasites are so minute and inconspicuous that they are very seldom observed, and we have no very positive data as to the numbers in which they may occur, so while they may be a very constant factor in control, it is doubtful if they can be credited with very much influence in reducing the numbers. The group is one of special interest on account of the peculiarity of structure and habit, and is one which may well be given much more extended study than it has yet received.

SPIDERS.

The great abundance of spiders in pastures, meadows, and grainfields is often most manifest by the immense number of webs that may be seen, especially on dewy mornings. These webs, however, tell only part of the story as there are a great many species of jumping and running spiders which construct no web to capture their prey and among these there are to be counted some of the most numerous and active insect feeders of the fields. These spiders are often taken in large numbers when sweeping for leafhoppers and that they feed readily upon the hoppers is proven by finding them with hoppers in their grasp within a few seconds after their capture in the net. Direct observation on unconfined individuals is difficult, since both spiders and leafhoppers are so hard to watch, but enough has been seen to justify the opinion that spiders are among the most widely distributed constant and effective agents in keeping leafhoppers in check. Exact observations on particular species to determine their relative value as leafhopper feeders, and to learn as to the relative value of adults or young spiders in such captures and their relative attacks on young and adult hoppers would be of great interest. Very likely the younger or weaker hoppers are preyed upon, especially by the smaller species or the young spiders. Mr. J. H. Emerton, the well-known authority on spiders, informs me that many different species are useful in this manner and he has kindly indicated a number of the species that he believes to be most efficient in this manner. Among these are the *Xysticus triguttatus* Keys., a species especially abundant in grasses and well adapted for leafhopper capture, and the different species of the genus Misumena, which are abundant in grasslands and low vegetation even up to high altitudes.

The species of Philodromus are among the forms that construct no web, but capture their prey at large and are active feeders on leafhoppers. The genus Phidippus, including a number of species of the jumping spiders, are also very active in this work.

The species of Dendryphantes, especially *militaris* Hentz and *suturalis* are considered by Mr. Emerton as among the most active leafhopper feeders.

Mr. Nathan Banks, another well-known authority on spiders, has given me the following list of species which probably feed on leafhoppers:

Epeira trivittata Keys., one of the most common web-making species; *Oxyopes salticus* Hentz, which is very common in the South; *Thanatus rubicundus* Thor.; Phidippus, especially the young, and mostly *P. rufus* Hentz and *P. audax* Hentz; *Thiodina retaria* Hentz; *Tutelina elegans* Hentz; *Agelena nævia* Walck.; *Mangora gibberosa* Hentz or *M. maculata* Keys.; *Plectana stellata* Hentz; *Epeira pratensis* Hentz; *Tetragnatha laboriosa* Hentz.

When we consider the carnivorous habit and observe the immense numbers of spiders in the fields, and realize that in many cases leafhoppers are the most abundant and accessible food supply for them, it is easy to credit the spiders with immense service in this direction.

REMEDIAL MEASURES.

The various methods of control for leafhoppers may be discussed under the general head of remedial measures. Some of the particular modes of treatment, applicable to certain species and to particular conditions of culture, must be discussed in connection with the species concerned. Practically all of the measures available must be adapted for the seasons or conditions of crop and consequently to advise any general method, applicable in all cases, is impossible.

CULTURAL METHODS.

Under the head of cultural methods we may discuss the effect of different plans of cropping, or the rotation or alternation of different crops, and this is, in many cases, one of the most effective means in keeping leafhoppers in check. The general immunity of spring wheat, in the northwestern wheat-growing regions, is quite certainly due to the effect of the methods of culture prevailing there, which do not permit a general infestation of the wheat fields; as, during the time when the insects would scatter for the deposition of eggs, the fields to be planted in wheat are mostly bare and furnish no attraction for the insects. In the case of the northern wheat regions, as in Pennsylvania, another condition is evidently to be considered and this is extreme cleanliness of the culture, the fields being cultivated so close to the fences that scarcely any grassland remains, as is the case generally where the dispersal of the leafhoppers occurs. Another very evident condition is the accumulation of hoppers in fields which have been continually in grass for a number of years. In such cases they occur in immense numbers, even as high as a million or more to an acre and the resulting injuries become serious. Contrasting this with fields in grass only one or two years it appears quite evident that rotation tends to eliminate the leafhoppers and that it requires two or three years of continuous grass to give opportunity to the leafhoppers to reach their full numbers. In sections where there is a general plan of rotation so that grass occupies certain fields for not more than one or two years, injuries are restricted to such an extent that they may be ignored. A striking instance of this was noticed on the North Dakota Agricultural College farm (see Pl. II, fig. 1), where a pasture in brome grass (Pl. I, fig. 2) for several years was badly infested, while nearby fields recently planted in grass were nearly free. When permanent pastures are in woodland, where rotation is obviously impracticable, it is evident that other measures must be adopted in any control to be secured.

MOWING.

The possible control of the species by the cutting of the grass depends upon an adjustment of the mowing to about the time when the insect is present in the egg stage or at such an immature larval condition that it is unable to migrate from the fields; at such times close mowing of the grass will remove such eggs as may be included in the leaves or stems and by exposing the young larvæ to a shortage of food as well as to the direct action of the sun, serve very materially in their reduction. A somewhat similar effect may be produced by providing for the very close pasturage of the grasslands during a certain period, if possible to correspond with that of the egg deposition of the more common species, alternating with a period of absence of stock from the field so that the grass may have a period of rapid growth.

BURNING.

Undoubtedly one of the most effective means of destroying the eggs of the leafhoppers in autumn or early spring is the burning of the dead grass wherever this means is practicable, and it may be resorted to with the assurance that much will be accomplished. The difficulty in this treatment arises from the fact that some grasses will not withstand burning except when the ground is frozen or wet enough so that the heat will not penetrate the surface and that, in cases where fields are freshly seeded to grass, the young plants may be injured by this treatment. This process is, perhaps, most available in the prairie regions, where the accumulation of dry material at the surface of the ground furnishes abundant opportunities for the application of fire for the destruction of eggs and hibernating forms, occurring in the locality. It is also especially applicable to the alternating strips of grass, in the localities where wheat and grass are planted side by side. Direct observations on this plan have shown some good results, but it has not had general use under conditions giving accurate results. In the prairie regions, before general settlement, the prairie fires were of very common occurrence, and while we can not determine just how much they have accomplished in the control of these insects, it is worthy of note that pasturage on these plains was of a very excellent quality and of long duration. One of the most positive evidences of the effectiveness of burning came under my observation in the spring of 1910 in Ottawa County, Kans. On a level tract of grassland adjacent to a stream, part of the surface had been burnt over a short time previously and the burnt tract was practically free from leafhoppers while the adjacent unburnt area, under otherwise identical conditions, was abundantly infested with hoppers of several different species. Even where the areas examined were closely adjacent or the burnt patches were surrounded by unburnt grass the difference was very noticeable. This was evi-

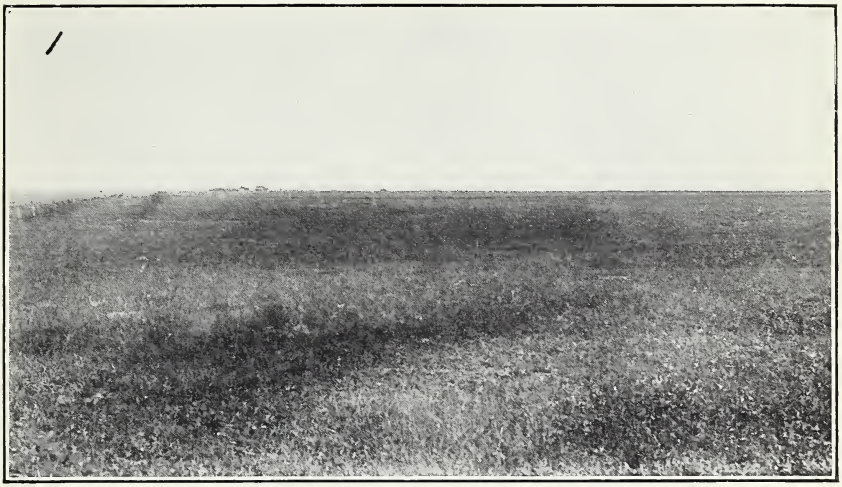

FIG. 1.—AN OLD MEADOW OR PASTURE NEAR ADA, MINN., WITH A MIXTURE OF GRASSES AND WITH FULL INFESTATION OF LEAFHOPPERS. (ORIGINAL.)

FIG. 2.—A BROME-GRASS PASTURE ON THE AGRICULTURAL COLLEGE FARM AT FARGO, N. DAK. IN GRASS FIVE OR SIX YEARS AND BADLY INFESTED WITH LEAFHOPPERS, ESPECIALLY DELTOCEPHALUS CONFIGURATUS. (ORIGINAL.)

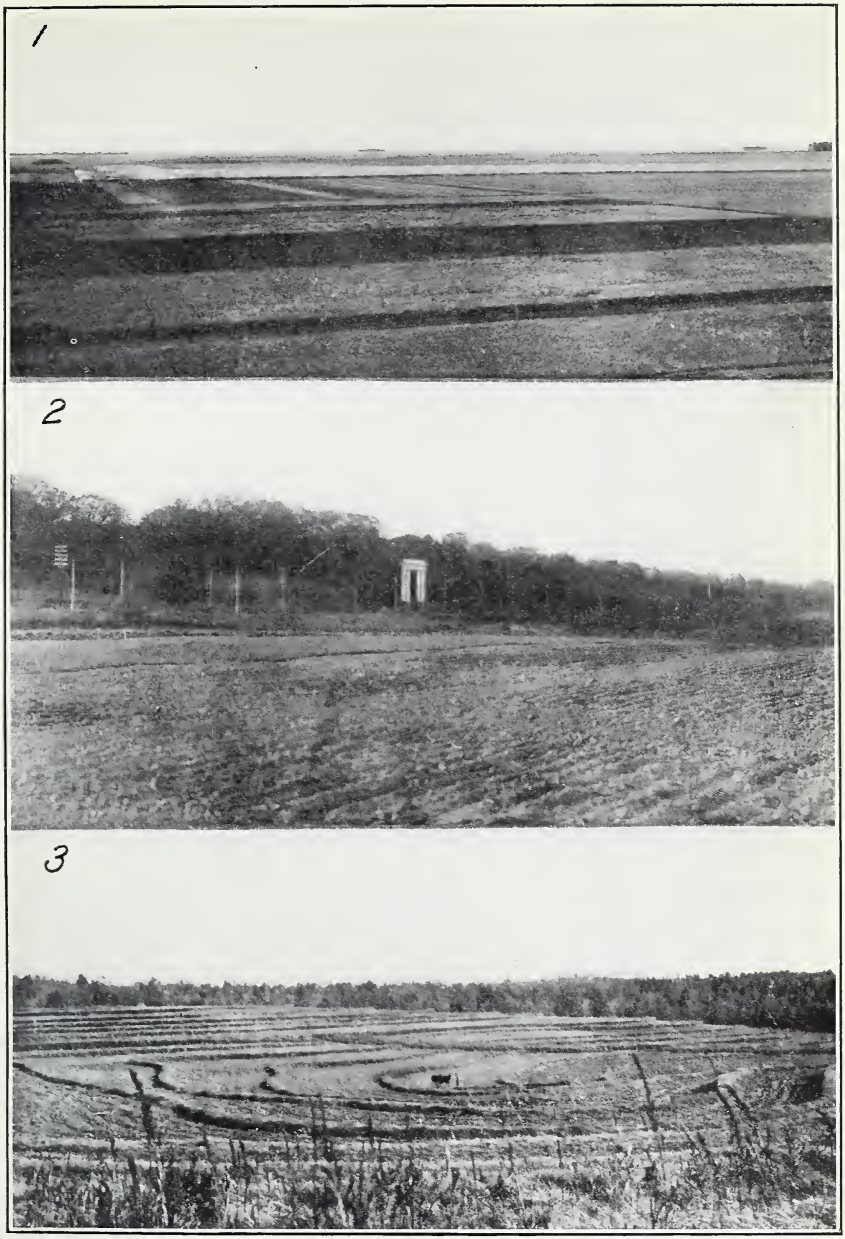

FIG. 1.—EXPERIMENTAL PLATS ON THE AGRICULTURAL COLLEGE FARM, FARGO, N. DAK.; NEW PLANTINGS AND WITH CLEAN ROADWAYS SEPARATING THEM FROM ADJACENT FIELDS. THESE PLATS WERE NOTABLY FREE FROM LEAFHOPPERS, ALTHOUGH FIELDS NEARBY WERE AFFECTED. (ORIGINAL.)

FIG. 2.—EXPERIMENTAL PLATS OF THE U. S. DEPARTMENT OF AGRICULTURE AT ARLINGTON, VA. IN AUTUMN WITH BUT NARROW SEPARATION FROM INFESTED GRASS PLATS OR STRIPS AND SHOWING CONSIDERABLE INFESTATION BY MIGRATION. (ORIGINAL.)

FIG. 3.—A TERRACED FARM IN SOUTH CAROLINA SHOWING THE UNCULTIVATED TERRACE STRIPS IN WHICH THE LEAFHOPPERS BREED AND FROM WHICH THEY READILY MIGRATE TO THE CULTIVATED CROP ON THE LEVEL. (ORIGINAL.)

dently on account of the quite recent burning and the fact that unfavorable weather had kept the hoppers so inactive that there had been little migration from unburnt to burnt portions. With so positive a case as this along with many others of nearly equal certainty it seems entirely warranted to recommend burning for such pasture lands and range as can be treated in this manner without detriment in other ways.

CAPTURING IN HOPPERDOZERS OR TAR PANS.

The direct treatment which has had the most thorough trial is the use of the hopperdozer, which consists of a sheet-iron strip coated with coal tar. The apparatus is drawn over the grass and the insects, hopping at its approach, fall upon the surface and thus many of them are killed. In a number of tests of this method at the Iowa Agricultural Experiment Station it was found that, in pastures ordinarily infested with leafhoppers, the insects could be captured at the rate of a half million to a million to the acre, which very appreciably reduced the number occurring in the treated fields. Probably three-fourths or more of the hoppers occurring in any particular area were captured by one or two treatments of this kind. It was found that this treatment could be applied to best advantage during the latter part of the afternoon on sunny days, when the insects would jump with the greatest facility and could be caught in the greatest numbers. In one experiment with this plan, two equal areas were treated for a season, and a comparison of the hay for the area showed an increase for the treated plat of more than 50 per cent. Two lots of bluegrass were used in an experiment, each containing about one and three-fourths acres. These were fenced. One plat was treated, leafhoppers being collected from it in large numbers at various times, and upon this plat cattle, varying in numbers, had been pastured at different times throughout the season for a period of about 73 days. On the other, untreated, a single cow was pastured. A comparison of the number of animals on each plat, taking into account their relation with the plat and the time during which they were pastured upon the area, shows that the treatment gave a gain of 68 per cent in the capacity of the pasturage. While this test may not be taken as an exact measure of the advantage to be gained in other cases, it should stand as an approximate gain for that test. However, it is evident that migration of these insects from adjacent areas would tend to reduce the advantage of the treatment, especially in a small tract, and that the greatest advantage could be secured from treating an entire pasture, so that there would be no opportunity for reinfestation from adjacent lands. The expense of this method of treatment is not great, it being estimated that in a section suitable for farm operations it may be easily performed at a cost of 7 cents per acre.

SPRAYING.

Since the perfection of spraying apparatus, it is possible to apply broadcast sprays of insecticides over any pasture lands or meadows, or even cultivated fields, where the crop is not so far advanced as to prevent access to the surface of the land. Such treatment, so far as the mechanical features are concerned, would be entirely practicable. At the North Dakota Agricultural Experiment Station such a broadcast sprayer is used for treatment of the fields to kill weeds and, using a kerosene mixture or emulsion, it would seem that very effective results on the leafhoppers could be secured.

SOME PREVIOUS RECORDS OF INJURY.

While actual records of appreciable damage are not abundant, there are a number which clearly show the possibility of destructive abundance and it may help to emphasize this to present a few such records. Most of these are in publications not now commonly accessible to most farmers, while some of them will probably appear new, even to professional entomologists.

One of the earliest records of this kind is for Illinois, 1875. Perhaps the most definite and fully reported is given in Prof. Comstock's report as Entomologist in 1879, which is given in full under *Cicadula exitiosa*. Another, from Orangeburg, S. C., November 20, 1893, reads as follows:[1]

> I send you to-day by mail sample of flies or insects which are infesting the small grainfields in this part of the country * * * 14 miles east of C. H. * * * and in some instances *completely destroys* the oats and rye. These insects appear in *great numbers* and when the oats and rye are just up they completely destroy it. After it gets a good root and begins to spread out they do not kill it out so bad but keep it from growing and it looks sickly and small. What is the name of the insect and how can we get rid of it? Under the glass it looks like a locust—can fly and hop. In young rye planted for grazing they are now in great numbers—millions—notwithstanding we have had several good frosts. I have been in several counties lately and I see them everywhere, but not so numerous as on my place. In some places they have destroyed the young turnips. * * *

A particular instance that came under the observation of the writer and was reported in Insect Life, Volume IV, page 197, 1891, occurred in the city of Washington on a newly planted lawn on the grounds of Prof. C. V. Riley, then the Entomologist of the department. In this case the effect showed very plainly in shrunken, withered plants in spite of abundant watering.

The bureau records include a number of more or less detailed reports for the country, usually without definite determination of the species causing the injury.

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[1] See Insect Life, vol. 6, p. 267, 1894.

Records of the Bureau of Entomology.

The records of the Bureau of Entomology made by Prof. F. M. Webster and his assistants, namely, Messrs. C. N. and G. G. Ainslie, E. O. G. Kelly, W. J. Phillips, G. I. Reeves, T. D. Urbahns, and V. L. Wildermuth, show the occurrence and more or less injury to crops in the following localities and for the crops mentioned:

At Huntsville, Ala., on wheat in the years 1905–6, the record for 1905 being November 5 "from a field of young growing wheat," and in this record, out of 222 insects taken 103 were jassids.

In Indiana Prof. Webster reported jassids on wheat at Lafayette in the years 1885–1891, and the records, especially for two of the species, will be mentioned farther on in reference to those particular species. At Osgood in 1890 he reported jassids as excessively abundant in fall wheat and that under the impression that they were Hessian flies the farmers reported considerable injury. A further report from Oxford in 1884 stated that *mollipes* occurred in oats and that in the second internode a cluster of larvæ was found. "Straw when grown did not seem to be withered or show any other effects except possibly premature ripening; searched assiduously, but found no others."

In Kansas jassids were reported at Concordia on wheat in 1905 and at Manhattan in 1907. They were abundant on young volunteer wheat. They were reported on September 8, 1908, at Wellington, the cast skins on wheat showing the development of the jassids on this plant. At Mulvane and at Sedgwick they were reported on March 26.

In Kentucky an infestation was reported at Fulton for 1905. In Nebraska they were reported for alfalfa September 1, 1909.

In New York two species, *Dræculacephala mollipes* and *Athysanus exitiosus*, were collected from bluegrass November 20, 1909. They occurred at the base of the grass.

In North Carolina jassids were reported as occurring on corn in the years 1907 and 1909. The work of *D. mollipes*, in the latter year particularly, will be referred to more in detail under that species.

In North Dakota they were reported as occurring on grasses at Tower City during the years 1905 and 1906.

In Oklahoma they were reported at Woodward on wheat in 1905, at Duncan on oats in 1908, at El Reno on wheat in small numbers in 1908, at Enid and at Stillwater as very numerous, and at Pawnee as occurring on both wheat and oats.

For Pennsylvania reports of their occurrence are given for Marion on bluegrass in 1909.

In South Carolina they were reported as collected on wheat in 1909, Mr. George G. Ainslie stating that in a field of wheat near the experiment station he found the grain swarming with one or more

species. Not having a net, he collected only two specimens. "There were spots and blotches on the fresh blades which may have been made by these bugs, but I was unable to catch any in the act. A movement of the grain raised a cloud of the hoppers." They were also reported for 1908 as occurring in numbers on barley and alfalfa at the same place and at Spartanburg on corn June 2 and 3. Reports of damage to cowpeas in 1908 and 1909 indicate serious injury. "The larvæ were in all stages and were found almost altogether on the underside of the leaves. A few were seen on the petioles. Usually not more than one was to be found on one leaf."

In South Dakota they were reported as affecting alfalfa in 1905.

In Tennessee there is a record of their occurrence on wheat at Union City in 1905 and at Knoxville on rye and oats in 1908. The record of occurrence on rye states that they were numerous in all stages on the small plants that had been cut and then stooled out. The jassids were on the leaves "way down into the crown of the plant." There is also a record for the occurrence on peanuts in 1908.

A number of records are given for the State of Texas, those for wheat being from Paris (1905), Arlington, Dallas, Corsicana, Greenville, and Whitesboro in 1908, and on oats for the same year at Arlington, Dallas, Corsicana, Greenville, and Whitesboro. There is a record for grass at Sinton, where it is stated that the jassids abounded everywhere upon Bermuda and other varieties of grass growing in damp places near the water tank and creek. At Denison, Tex., they are reported as occurring on barley, and the report states that a small field of barley, about one-fifth acre, had been killed outright a week or ten days previously by Toxoptera. No sign of the latter could be found, but there was an abundance of Jassidæ, all of one species. These were the prevalent insects at the time of the outbreak. This species was determined as *Cicadula 6-notata*. At Ringgold they were reported as numerous in one oats field and damaging the plants. The cast skins were numerous on the leaves (which would prove development on oats). On March 17, 1908, there were few adults. At Whitesboro on oats they were reported very thick, causing red spots to occur, the cast skins hanging to the leaves, but no adults among them. At Grand Prairie in September, 1907, they occurred on grass. At Dallas in 1909 they were infesting alfalfa and sorghum; in some cases they were very numerous and causing injury; in others no injury was apparent.

At Charlottesville, Va., they were reported on alfalfa for October 5, 1906. These were from an alfalfa field on the farm of E. C. Massie and from borders of the field also. Mr. Massie claimed that the alfalfa came up nicely and was almost at once eaten up; there is no absolute certainty that the species collected were concerned in the destruction of the alfalfa, but they were abundant in the immediate vicinity of the field.

At Pullman, Wash., wheat was infested in 1908 on the college farm, the reports referring particularly to presence in volunteer wheat.

In the District of Columbia there is a report for occurrence on clover in 1909, and also for the occurrence and rearing of adults of *Empoasca flavescens* Fab., *Deltocephalus nigrifrons* Forbes, and *Liburnia puella* Van D. from *Panicum proliferum*.

OBSERVATIONS DURING THE SEASON OF 1909.

During the season of 1909 it was possible for me to make observations in a great number of different and widely separated localities and this furnished a basis for comparison of the conditions in different parts of the country. A general summary of these comparisons may be instructive.

Starting in Iowa in the middle of June observations indicated but little injury from leafhoppers in the grain fields and only the ordinary amount of abundance in grassland—perhaps less than in many seasons on account of the lateness of the season and extremely wet weather conditions that had prevailed earlier in the season. In the Missouri Valley section wheat fields were practically free from jassids, as also from any indications of injury from aphidids, Hessian fly, or joint-worm. Fields of alfalfa intermixed with volunteer wheat and clumps of grass were infested with the usual species, but not in great abundance. In timothy, *Deltocephalus inimicus* was present but in moderate numbers. Farther north, at Vermillion, S. Dak., these species were present in wheat fields, but usually where some grass was present and there was little indication of direct infestation of spring wheat.

At Brookings, S. Dak., the extensive plats of wheat and grass gave an opportunity for ready comparison of the attack on different kinds of grains and grasses, but jassids were nowhere plenty. The greatest abundance occurred in fields of native grasses or where a considerable abundance of native grass was present. This included the usual species occurring in prairie grasses and in such abundance that they could be considered of economic importance. The importance of these prairie grasses is recognized, and the writer was told by Prof. James Wilson, director of the station, that they are much used for hay, the method being to cut every two years, and the dried grass of the year previous is said to be equally valuable for forage with the fresh growth. If cut in this manner it can be raked and stacked at once.

At Fargo, N. Dak., jassid injury to wheat, oats, or spring-planted grains was not observable, although a few individuals were to be seen here and there. A few jassids that were afterwards gathered from the examination of a large number of fields in this section indicated that jassid injury to the spring-planted grains is practi-

cally a negligible quantity, and that under the present methods of cultivation in the wheat-growing section of the Red River Valley these insects may be excluded from consideration. In permanent grasslands, however, the situation is quite different, as the author found, especially in fields that have been two or more years in timothy or other grasses, a considerable abundance of leafhoppers, especially of *Deltocephalus inimicus* and *D. configuratus*, with other species in less numbers. One of the most abundant infestations was noted in a field of brome-grass (see Pl. I, fig. 2) which had been planted for about five years and which was used at the time as a pasture. Alfalfa in this section showed little infestation. The prairie grasses showed a considerable abundance of the usual species.

At Ada, Minn., an examination was made of a number of large wheat fields, and these were mostly free from jassids, as were also pasture lands which had recently been planted, but older pasture lands (see Pl. I, fig. 1) included considerable numbers of *Deltocephalus inimicus* and *D. affinis*. The wild grasses of this locality included the same species as were found at Fargo.

At Bismarck, N. Dak., no wheat fields were studied, but a collection of jassids upon the range grasses showed a very abundant occurrence of the species of Deltocephalus, Athysanus, and Lonatura? In less numbers were species of Driatura, Chlorotettix, and Paraboloeratus.

At the substation of the North Dakota Experiment Station at Dickinson the author found a considerable number of plats of oats, millet, wheat, alfalfa, etc., and while jassids occurred in small numbers in a number of these plats they were not abundant enough to cause any appreciable injury. In wheat *Cicadula 6-notata* occurred very sparingly, as also in oats and millet. A rather unusual occurrence was that of *Philænus bilineatus* Say in oats. This is an abundant species in the field grasses and probably had migrated from these into the oats field. Upon the wild prairie land (see Pl. III, fig. 2), which includes a mixed assemblage of the buffalo grass, wild-oats grass, etc., there was an abundance of different species of Deltocephalus with some other genera. The range grasses here are of special importance, as they are pastured to a large extent and are also mowed for hay. Wild oats, a most conspicuous element, is said not to be particularly troublesome, and even after the barbs are well formed it is cut and used as hay. In some localities farther east it is looked upon as a distinctly troublesome form.

Near the Mammoth Hot Springs, Yellowstone Park, the writer secured a number of interesting species of Jassidæ upon the annual grasses but a particularly interesting occurrence was noted in a small patch of cultivated grass kept under irrigation (see Pl. III, fig. 3). This patch, located very remotely from any other cultivated grasses and including timothy and clover and some bluegrass, was found

to be fairly swarming with several species of the leafhoppers. The species in greatest abundance was *Deltocephalus affinis* and the next most abundant was probably *Cicadula 6-notata*, then *Deltocephalus debilis* Uhl. with *D. inimicus* very scarce or wanting. How the species ordinarily occurring on cultivated grasses have reached this isolated patch is an interesting question.

Another series of interesting records was made at Bozeman, Mont., on the grounds of the Montana Agricultural College. In plats of wheat, oats, and barley, *Cicadula 6-notata* was found fairly common but not abundant. This species appears to follow these crops entirely across the country throughout the Northern States and also to occur on some of the grasses.

At Pullman, Wash., wheat during this season was very free from jassids although I was informed by Mr. Geo. I. Reeves, of the Bureau of Entomology, of attacks of a species of Dicraneura. Cultivated grasses, however, were considerably infested, timothy by *Deltocephalus inimicus* and *D. affinis*, and a red-top grass by *D. inimicus*, *D. affinis*, *Cicadula 6-notata*, and *Thamnotettix geminatus*. Both clover and alfalfa were infested in considerable abundance by *Athysanus exitiosus*, *Cicadula 6-notata*, and *Deltocephalus inimicus*. Wild grasses of this vicinity show a great variety of leafhoppers, and it would appear that they are quite an important economic problem.

At Kalispell, Mont., the wheat fields appeared to be entirely free from leafhopper injury, a few leafhoppers only being found in volunteer wheat and oats along the roadsides. The usual species, however, were found in considerable abundance in the autumn grasses and a number of species in the wild grasses growing on the unbroken land. One of the most conspicuous species here was *Athysanus sexvittatus* Van D., which was taken especially from a tall red-top grass (Festuca?).

At Williston, N. Dak., on the grounds of the North Dakota Agricultural Experiment Station, the jassids were found on wheat, oats, alfalfa, and clover, but not in any case in such abundance as to be a serious menace to the crops. *Deltocephalus inimicus* and *Cicadula 6-notata* were the most frequently met. The annual grasses showed rather more than the usual abundance and possibly from the lateness of the season or because of the dryness of the grasses in this locality showed more than the usual amount of withering. A field which had been flooded earlier in the season included very few jassids and suggests the possibility that they may have been quite extensively drowned out. Alfalfa of the 1908 planting was free from jassids, while the fields of Bermuda grass of the second year's planting had a much greater abundance than on the first year's plants. In spots here and there were *Deltocephalus inimicus* and *D. nigrifrons*, *Cicadula 6-notata*, and *Dræculacephala mollipes*. Collections were also made at Devil's Lake and Grand Forks, N. Dak., but with little difference in the char-

acter of the collections made and the second examination of the fields at Fargo, N. Dak., July 29, showed about the same condition as had been observed a month earlier with possibly a somewhat greater abundance of the common species in clover and timothy.

Summing up in brief the observations in the northwestern States visited on this trip, it may be stated that leafhoppers were of very infrequent occurrence and practically of no economic significance at this season in the fields of wheat and oats but that the numbers occurring in the range land as well as in pastures and meadows were sufficient to cause a considerable drain upon the crop.

Observations made by the author in Ohio, covering points at Akron, Wooster, Sandusky, Toledo, and Columbus, with other points in the central part of the State, showed only a moderate amount of jassid injury for the season and little indication of attack on fall wheat, although these observations were made too early in the season to determine fully in this regard. At Akron an interesting occurrence of *Deltocephalus apicatus* Osb. was observed, and the food plant for the species there positively determined as *Panicum huachucæ*. This was found occurring on little clumps of its host plant in a meadow, including clover, bluegrass, and timothy. This leafhopper would be found strictly confined to the little patches, not occurring on adjacent grasses or other species. At another point it was taken in large numbers from a small patch where no other grasses grew and individuals of different sizes, representing stages nearly all the way from newly hatched to adult, were found. So abundant was it at this point that about 150 specimens were taken at one sweeping. The host plant (*Danthonia spicata*) for *Deltocephalus melscheimeri* was also found on a woody hillside where the grasses grew practically isolated so that there could be no question as to the host of the leafhopper.

At Urbana, Ill., in meadow land, including timothy, clover, etc., jassids occurred in large numbers, including *Deltocephalus inimicus*, *D. nigrifrons*, and *D. sylvestris* Osb. and Ball in open fields, and *D. weedii* Van D., *D. sylvestris*, etc., in a woodlot.

In Indiana at Lafayette and vicinity the pasture land examined was found to include the usual forms and in about the ordinary abundance. In a field of soy beans a few specimens of *Empoasca mali* were found, several larvæ and a few adults, showing conclusively that the life history of this species was passed on this crop. Mr. W. J. Phillips informed me that he had found it quite common earlier in the season and noted a distinct injury due to its presence. Most of the other plants in the field, except the variety in which were found specimens, were dead and the leafhoppers had doubtless migrated from them to find fresh food. Plant-lice were also found upon the same plants, but not in numbers to cause much injury. Alfalfa was found to be infested quite freely with *Empoasca mali*, both larvæ and adults, and there were also several other species of leafhoppers, *D. inimicus*, Agallia, etc. An opportunity

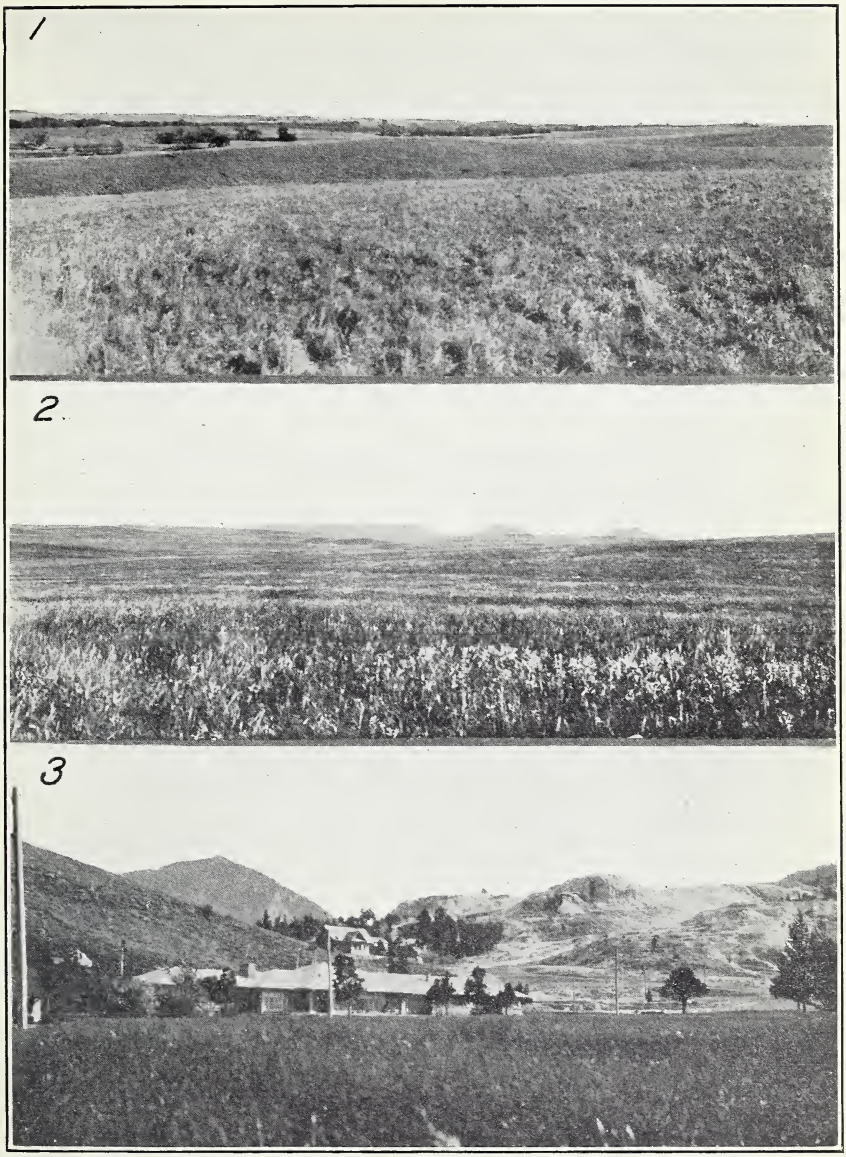

FIG. 1.—WILD GRASSLAND IN CENTRAL KANSAS, INCLUDING GRAMA GRASSES, BUFFALO GRASS, ETC., AND WITH AN ABUNDANT SUPPLY OF LEAFHOPPERS OF THE GENERA DELTOCEPHALUS, ATHYSANELLA, ETC. (ORIGINAL.)

FIG. 2.—WILD GRASSLAND AT DICKINSON, N. DAK., WITH BUFFALO GRASS, GRAMA GRASSES, AND OTHER NATIVE GRASSES AND WITH GREAT ABUNDANCE OF LEAFHOPPERS—DELTOCEPHALUS, ATHYSANUS, ETC. (ORIGINAL.)

FIG. 3.—SMALL PATCH OF CULTIVATED IRRIGATED GRASS IN FRONT OF MAMMOTH HOT SPRINGS HOTEL, YELLOWSTONE NATIONAL PARK, WHICH WAS SWARMING WITH LEAFHOPPERS COMMON TO THE CULTIVATED SPECIES, NOTWITHSTANDING ITS REMOTENESS FROM ANY OTHER CULTIVATED GRASS.

was found to note the migration of leafhoppers into wheat from adjacent grass, as a plat in the experimental grounds where the wheat had only recently come up and which was practically free from any other kind of vegetation was found to be infested with *Deltocephalus inimicus* and *D. nigrifrons*. Collections at Indianapolis gave no particulars different from those which have been observed in other localities.

October 20, at Hamburg, N. Y., the author found leafhoppers quite active, and in a series of narrow strips of wheat alternating with grass it was distinctly noticeable that the leafhoppers had migrated into wheat strips in considerable numbers. In another larger field not far distant the central part of the field appeared to be less infested and it would seem that the distance from adjacent grasses had been a factor in the lesser infestation. This field, however, was too small to give a very good opportunity for noting the distances to which the leafhoppers can easily migrate.

At Valencia, near Pittsburgh, Pa., November 2, the author found *Deltocephalus inimicus* and *D. nigrifrons* with *Phlepsius irroratus*, *Cicadula 6-notata*, and a species of Balclutha, all in small numbers, probably because of the rain and cold which must have driven them to shelter. Some were found under dead leaves, but others had been exposed, as their movements were sluggish. Most of the leafhoppers seemed to be very well prepared for hibernation, at least were too inactive to furnish much opportunity for examination.

In the vicinity of Harrisburg, Pa., November 4 and 5, several fields were visited, and practically no jassids whatever were found in the fall wheat, a condition which seemed quite puzzling, since the weather was warm enough so that the jassids should have been active. The author learned, however, that the protracted drought had dried up the vegetation in early autumn and inasmuch as the fields examined were mostly upland and as the small amount of grass adjacent had probably been too small to support the jassids earlier in the season there had been no infestation of the wheat. In one field of grass, distant from the wheat fields examined, a small number of *Deltocephalus inimicus*, *D. nigrifrons*, and *Agallia sanguinolenta* as well as a Liburnia were found. The observations here appeared to be distinctly significant as showing the possibility of preventing injury to fall wheat by the elimination of jassids developing in the adjacent grass fields.

At Reading, Pa., November 6, on a bright, warm day, in fields east of the town, several species of jassids were found, among them *Deltocephalus sayi*, *D. nigrifrons*, and *Dr. mollipes*. Wheat fields nearby, however, were very clean, free from weeds or grasses, except timothy, which was just appearing above the ground. The jassids were quite few in the wheat, and in the central part of the field, excepting representatives from the adjacent grassland, very few were to be found and none at all at the center of a large field. In none of the

wheat fields examined could jassids be considered of economic importance, none were found under clods, and the scarcity here could probably be attributed to clean culture. In fall wheat at Newark, Del., November 9, very few jassids were to be found.

At College Park, Md., and Arlington, Va., the infestation with jassids was much more extensive than found at any of the other more northern localities and in both of these places was sufficient so that it might occasion noticeable injury. This is particularly true of plats which lie adjacent to strips of grass, such as those along roadways and by the borders of fields. At Arlington, Va., especially (see Pl. II, fig. 2), the conditions indicated the readiness with which the jassids will migrate into fall wheat or other cereal crops from the adjacent grass or from the volunteer wheat of a summers' growth. Individuals were found with the bodies distended as if filled with eggs, but egg laying was not observed, and the dissection of specimens revealed no completely developed eggs.

At Raleigh, N. C., November 15, the author found a particularly interesting location in an oats field which was nearly surrounded by grasslands with strips of grass along roadsides. The oats were very seriously infested with leafhoppers, especially *Deltocephalus nigrifrons*, *Athysanus exitiosus*, and *Dræculacephala reticulata*. *Cicadula 6-notata* was present but not nearly so common as the other species, while only a few specimens of *Phlepsius irroratus* were taken, and *Deltocephalus inimicus* was not observed at all. Many of the plants had leaves that were yellowed or withered and showed spots which had every appearance of being the result of punctures by these jassids. In the grass adjacent to this field all the species occurring in the wheat were found, and in addition *D. flavicosta* Stål, *Xerophlœa viridis* Fab., *Athysanus obtutus*, and *Platymetopius frontalis*. Evidently these latter species are not attracted to oats. It was also noticeable that the oats included only adults, and larvæ were found only in the grasses—another proof of the recent migration from the grasses into the oats, in which particular case it was very clear that treatment of the adjacent grasslands would have lessened if not entirely prevented the infestation of the grain.

At Columbia, S. C., November 16, in wheat fields near the city, an abundance of *Deltocephalus nigrifrons* was found which made up perhaps nine-tenths of the entire number of leafhoppers taken in the fields, while *Cicadula 6-notata* was not common, *Athysanus exitiosus* was quite common, *Dræculacephala mollipes* and *Dr. reticulata* were few, and *Athysanus obtutus* occurred in small numbers. These same species occurred in adjacent grasses, *Deltocephalus nigrifrons* being most abundant, other species in about the same proportion as observed for the wheat, and *Xerophlœa viridis* occurring in small numbers. As compared with conditions at Raleigh, N. C., *Dræculacephala reticulata* seemed considerably less abundant. At Clemson

College, S. C., conditions were much the same as at Columbia, S. C., but quite a noticeable infestation of grasses with *Deltocephalus nigrifrons* as the main element was observed.

At Decatur, Ga., November 19, grass pastures, including mostly Bermuda grass, showed an abundance of *Deltocephalus nigrifrons* with a few *D. obtectus* Osb. and Ball and *Athysanus colonus* Uhl., etc., both larvæ and adults, and a few specimens of *Phlepsius irroratus*. *Dræculacephala mollipes* and *Dr. reticulata* were common, the former in both larval and adult stages, the latter only as adults. The wheat examined was only slightly infested, but being inaccessible, bordered on one side by woods and on the other by a rather barren roadside, small opportunity was present for infestation.

At Knoxville, Tenn., November 22, the weather being bright and warm, jassids were found in abundance and quite active, and the infestation of fall barley especially was quite serious. This had been planted about the middle of September and had made a strong growth and included a large number of jassids, the most abundant species being *Deltocephalus nigrifrons*. Alfalfa fields planted several years were also infested extensively with a number of different species and also red clover two years planted, while the younger fields showed much less injury. It was noticeable that *Dræculacephala reticulata* was not found in any of the collections here, an indication that its present limit of distribution is farther south for this meridian, though farther east and on lower levels it goes much farther north.

OBSERVATIONS DURING THE SEASON OF 1910.

During February, March, and April, 1910, I made a trip through the Southern and southwestern States collecting and studying the local conditions at a number of points.

At Biloxi, Miss., the species occurring in Bermuda grass were studied particularly. Here were found an abundance of the yellow-headed leafhopper *Dræculacephala reticulata*, with other species, and in some places these occurred in Bermuda grass where no other grasses were present. No larvæ of *Dr. reticulata* were found, although larvæ of other species occurred. It was evident therefore, that this species must hibernate in the adult stage.

At Brownsville, Tex., where I spent nearly a week, February 19 to 25, leafhoppers were becoming very active, although the first day or two was cloudy and cold, with occasional drizzling rain. Bermuda grass, oats, and the native wild grasses of the locality were all quite fully infested with different species of leafhoppers and many facts concerning their hibernation and life history were secured as well as the collection of many species not hitherto known from that region. *Dræculacephala sagitiffera* Uhl. was very abundant and apparently replaced *Dr. reticulata*, which I did not collect.

February 26 and 27 were spent at Corpus Christi, Tex., but high winds and cloudy weather interfered somewhat with best results in

collecting. Some especially good records, however, were secured with reference to the food plants and habits of species occurring on the native grasses. (See Pl. IV, fig. 3.)

At San Antonio, Tex., February 28 and March 1, most of the time was spent on the Collins irrigation farms and at the Government experiment station, which furnished an excellent opportunity to compare the conditions in irrigated and nonirrigated areas. (See Pl. IV, fig. 2.) In both places a number of the common species were present, but the abundance differed very decidedly for some of them, showing that they flourished much better in the moist locality.

At El Paso, Tex., the hillsides presented a very barren condition, the grasses being absent or completely dried up and no leafhoppers were found in these localities. In a small irrigated tract near the city several species were fairly swarming and I found here also a species of Stictocephala quite abundant in grass. At Tucson, Ariz., several days were spent, March 6 to 9, where the assistance of the officers of the Desert laboratory and of the Arizona College of Agriculture was obtained. Collections from the cultivated plats of barley, grasses, and alfalfa, as well as from the native desert grasses (see Pl. IV, fig. 1) were made.

At Tempe, Ariz., in the irrigated sections of the Salt River Valley, where many forage crops are grown and where wheat has been cultivated probably for many centuries, particular attention was given to the wheat fields and alfalfa, clover, and grass. A number of the common widely distributed species occurred here and some of these in considerable abundance, although in no case were they so plentiful as to be causing noticeable injury.

At Yuma, Ariz., and Fort Yuma, Cal., considerable numbers of leafhoppers occurred in the irrigated fields of alfalfa, clover, and wheat. On Bermuda grass and in some of the native grasses in nonirrigated fields a number of species were secured evidently belonging to the native fauna.

In the irrigated section of the Imperial Valley collections were made at El Centro and Brawley, Cal., and a variety of crops, including barley, oats, alfalfa, and Bermuda grass, were examined. Very few leafhoppers were found in the oats and barley, but the alfalfa was infested considerably, and the Bermuda grass included several species that were fairly plentiful.

In the vicinity of Ontario, Pomona, and Chino, Cal., there were opportunities to examine fields of alfalfa, oats, barley, and Bermuda and native grasses, but for the most part leafhoppers were very scarce and in some fields only one or a very few specimens could be discovered after dilligent search. On alfalfa the most common species of leafhopper was an Agallia. The native grasses were but slightly infested and very few species were represented.

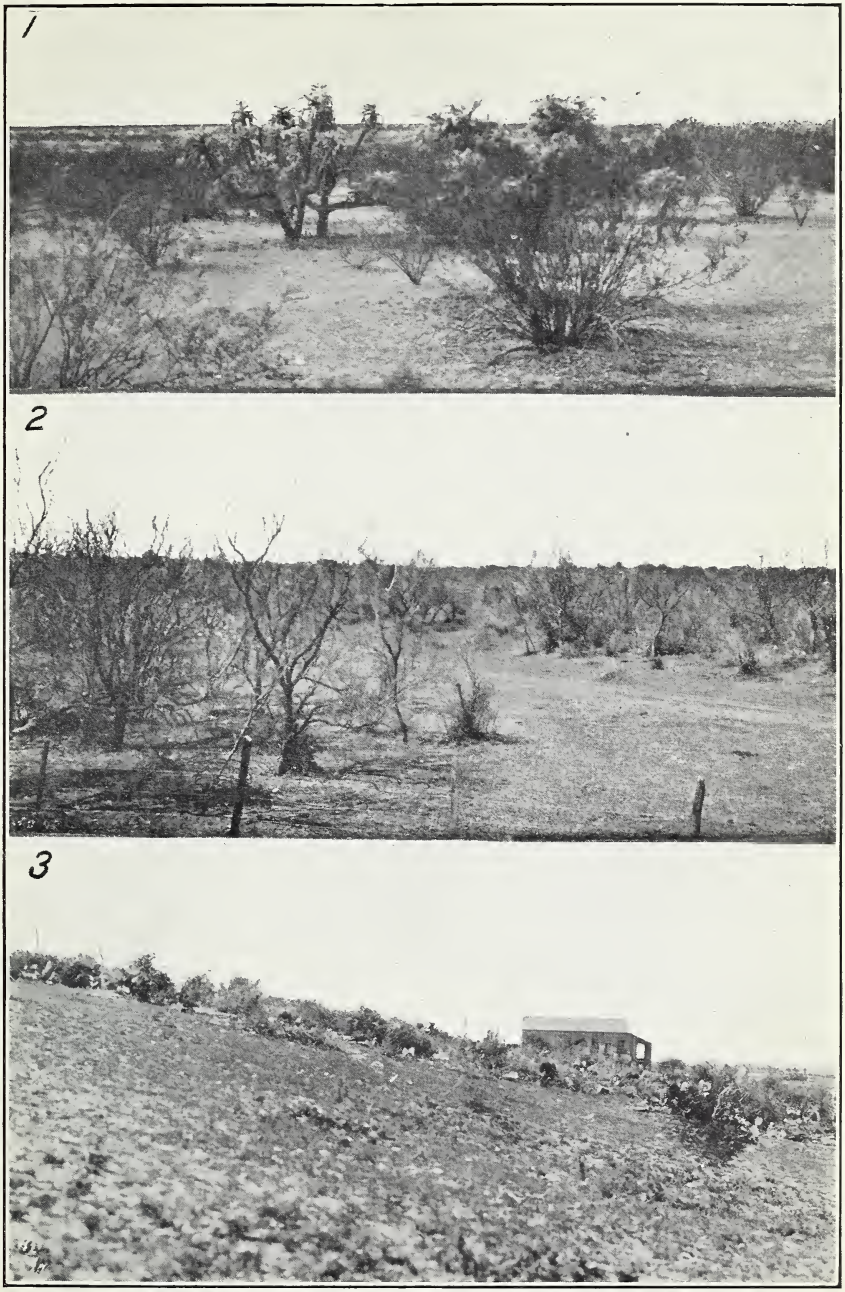

FIG. 1.—DESERT NEAR TUCSON, ARIZ. THE SMALL GRASSES OCCURRING IN SCATTERED CLUMPS AMONG THE DESERT VEGETATION OF CACTUS, CREOSOTE BUSH, ETC., ARE THE HOME OF VARIOUS SPECIES OF LEAFHOPPERS WHICH SURVIVE IN SPITE OF THE EXTREME DRYNESS OF THE HABITAT. (ORIGINAL.)

FIG. 2.—DESERT WEST OF SAN ANTONIO, TEX. HERE THE PLAINS GRASSES THAT ARE COMMON IN THE MESQUITE ARE FAIRLY SWARMING WITH LEAFHOPPERS OF SEVERAL DIFFERENT KINDS, ESPECIALLY THE ATHYSANELLAS. (ORIGINAL.)

FIG. 3.—A BIT OF DESERT-LIKE HILLSIDE NEAR CORPUS CHRISTI, TEX., WITH CACTUS AND MESQUITE AND CLUMPS OF DESERT GRASS WHICH WERE FOUND TO BE ABUNDANTLY INFESTED WITH LEAFHOPPERS. (ORIGINAL.)

In the vicinity of Long Beach, Cal., several of the common species were plentiful in fields of mixed grass and clover and in the native salt grass near sea-level *Lonatura minuta* Van D. occurred in large numbers and in different stages. The barley fields were quite free from leafhoppers, as also the oats fields, although several of the common species were represented in the other fields.

Nearly the same conditions were observed at Sierra Madre, Cal., March 25. The fields of barley, oats, clover, and alfalfa were quite free from leafhoppers, the greatest abundance being found in a field of barley where *Athysanus exitiosus* was fairly common.

At San Diego and La Jolla, Cal., severe rains interfered with good work, but at the latter place a number of species were secured from grasses and oats.

At Whittier, Cal., on March 29, on a warm sunny day, leafhoppers were quite abundant in fields of barley, oats, grass, clover, and alfalfa, and in one field particularly on a southern hillside several species were swarming in great abundance in both larval and adult stages.

At Bakersfield, Cal., August 30, collections were made on wild grasses and other plants and particularly on clover, burr clover, and alfalfa. Several species were abundant. *Athysanus exitiosus* was plentiful, as also several species of Deltocephalus. Three species of Agallia occurred on clover and on a wild species of legume. Other species occurred in less abundance.

At Fresno, Cal., March 31, collections were limited to wild vegetation, but the *Athysanus exitiosus* was found abundant in both larval and adult stages. Deltocephalus of a black variety (*fuscinervosus* Van Duzee) was fairly plentiful and Agallias were swarming in some patches, evidently where the legumes were most plentiful.

At Modesto, Cal., March 31 and April 1, a number of fields of oats, barley, and alfalfa were examined, but the leafhoppers were not abundant. The scarcity of *Athysanus exitiosus* in oats fields would indicate its preference for the native grasses, at least for egg deposition.

Collections in the vicinity of San Francisco, Berkeley, Palo Alto, and Davis, Cal., gave slight results owing to unfavorable weather.

At Logan, Utah, wheat fields were apparently free from leafhoppers but the weather was too cold to favor their activity. Several species, however, were found active among the native grasses and larvæ of Deltocephalus and Cicadula were quite plentiful in some places.

At Grand Junction, Colo., April 17, jassids were active in alfalfa and the wild grasses of the locality.

At Pueblo, Colo., several species were found in bluegrass, the most abundant being *Deltocephalus affinis*. In the wild plains, grasses of several species were common and Athysanella very abundant.

At Colorado Springs, Colo., April 20, on the native grasses leafhoppers were swarming by millions, a number of different species being represented.

The conditions at Fort Collihs, Colo., April 22, were very similar although cold and high wind made the collection somewhat smaller.

In central Kansas, near Delphos, April 24 to 28, jassids occurred in great abundance in the native grasses, but were scarce in the wheat and other cultivated crops.

A short trip in northern Michigan to determine the range of certain species was made in the latter part of June, collections being made at Detroit, Mackinac Island, Sault Sainte Marie, and St. Ignace, most of the time being spent at the "Soo." *Deltocephalus abdominalis* occurred here in large numbers, both larvæ and adults being taken. *D. affinis, Cicadula 6-notata,* and other species were abundant.

SYSTEMATIC POSITION OF LEAFHOPPERS.

The insects which are commonly known as leafhoppers are included in the group of bugs, Hemiptera, and in the suborder Homoptera, which includes among other forms the cicadas, plant-lice or aphides, and the scale insects. The name is applied more strictly to the old family Jassidæ, the members of which as a very general thing have the habit of jumping quickly when disturbed, and since their usual habitat is the leaf or stem of plants the term leafhopper is very appropriate. This old family, however, has been subdivided, and there are now recognized three or four families, and the members of all of these may properly be included in a discussion of the leafhoppers in general. The species of economic importance in connection with cereal and forage crops are included in all of them, and there are so many points in which they have similarities of habit, and consequently are open to similar methods of treatment, that it is entirely logical to group them for the purpose of this paper. The most familiar examples of the groups are perhaps the grape leafhoppers, which produce so distinct a whitening or withering of grape leaves in the latter part of summer. The species with which we are more concerned are those which will be seen to rise in great numbers if disturbed from the grass in the pasture or meadow as one walks through the fields.

Aside from the forms included in the Jassidæ proper, the name "leafhopper" has been applied also to some of the "froghoppers" (Cercopidæ), also known as spittle insects, and some of these are so similar in their habits and attacks upon forage crops that mention of a few of them may be necessary. Further, the name "leafhopper" is very generally applied to members of the family Fulgoridæ, especially to the division Delphacinæ. These are minute insects with habits almost identical with those of the jassid leafhoppers infesting grasses, and since they are commonly confused with these, it will be desirable

to discuss some of the more important species in this connection. Outside of the United States some of these are recognized as among the most serious pests, as the sugar-cane leafhopper (*Perkinsiella saccharicida* Kirk.), which has in recent years caused a loss of many millions of dollars to the sugar crop in Hawaii. We have also a species common in the Southern States which attacks corn and which has, at times, been noted as very abundant and destructive. While it may appear unnecessary to discuss the details of classification or of structure in these various groups, the fact that some of the differences presented are such as to have a very important bearing on the distribution or the methods of control makes some such consideration necessary. Moreover, there is a quite important difference in the parasitic enemies which may be found to occur on the different forms, and this alone would be ground for a careful designation between forms which are essentially different although bearing the same common name.

EXPLANATION OF TERMS USED.

While it is possible in the description of the different insects treated here to use a number of common terms, such as head, wings, legs, abdomen, eyes, face, etc., and the descriptions are therefore intelligible to anyone so far as these go, it is necessary for the sake of precision in some instances to use terms which are less generally known, or at least not definitely applied. An explanation, therefore, of a few terms which are really necessary for the accurate description of the different forms mentioned will be given in order to make the paper of service to those who have no technical knowledge of entomology, but whose acquaintance with ordinary English should enable them to place the particular insects which are under discussion.

The term *vertex* is used for the upper surface of the head between the eyes and extending to the front border, which may merge gradually into the front or the face. The *frons*, or *front*, is the part of the face lying between the sutures and extending down nearly to the lower border. At the sides of this are portions next the eyes, which are termed the cheek and below the front a part called *clypeus*, at the sides of which are the *loræ*. The central part of the body which bears the wings and legs is termed the thorax, and the upper portion of the first segment is known as the *pronotum*. The front wings are termed *elytra* and are usually thicker and stronger than the hind pair, which are concealed beneath the front ones when at rest. The hinder distinctly segmented part of the body or *abdomen* may be entirely hidden above by the wings, but in short-winged forms is more or less exposed. The parts of greatest importance on the abdomen for purposes of description are the terminal segments, including the genitalia. In the female the last ventral segment is frequently of a particular shape or structure for different species, and in many groups is of the greatest service for description. It is followed by the sheaths of the

ovipositor, this latter being a narrow sawlike pair of blades extending to the tip, sometimes considerably beyond the tip of the sheaths. The males have for the terminal segment beneath a modified segment, called the *valve*, which is followed by two movable pieces called *plates*. Above these, forming the sides of the last segment, are the *pygofers*. A ready understanding of these various parts will be helped by a study of the accompanying figure 1, in which they are located

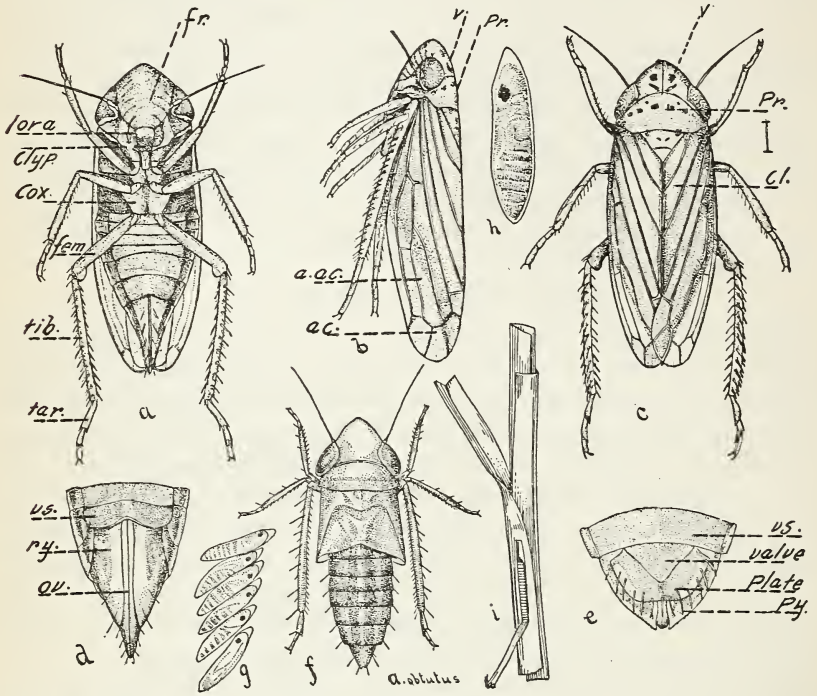

FIG. 1.—Explanation of terms from drawing of *Athysanus obtutus: a*, Female from beneath; *b*, from side; *c*, from above; *d*, female genitalia; *e*, male genitalia; *f*, larva or nymph; *g*, eggs, showing developing larvæ; *h*, egg, enlarged; *i*, eggs in position beneath sheath of grass stem. Structural details: *ac*, Apical cells; *aac*, anteapical cells; *cl*, clavus; *clyp*, clypeus; *cox*, coxa; *fr*, front; *fem.* femur; *lora*, lora; *ov*, ovipositor; *plate*, plate; *pr*, prothorax; *py* (♂), *ry* (♀), pygofer; *tar*, tarsus; *tib*, tibia; *v*, vertex; *vs*, terminal ventral segment; *valve*, valve. All enlarged. (After Osborn and Ball.)

and named. For the different stages of insects the usual terms egg, larva, or nymph, pupa, and adult are used, as these are sufficiently definite in indicating the steps of development from the egg to the mature form.

THE MORE IMPORTANT SPECIES AFFECTING CULTIVATED CROPS.

The Yellow-headed Leafhopper.

(*Dræculacephala reticulata* Sign.)

The yellow-headed leafhopper (*Dræculacephala reticulata* Sign.), an extremely abundant species in the southern United States, has been noticed a number of times as destructive in wheat or oats, but has never received any full discussion, and we are still ignorant as to the details of its life history. It was described by Signoret as

Tettigonia reticulata in 1854 from specimens derived from Cuba and without any statement concerning its importance. Later, in 1880, it was redescribed by Prof. C. V. Riley and renamed *Diedrocephala flaviceps*, and in connection with the description appears the note, "Numerous specimens injuring wheat and oats in Texas." In Insect Life there is a record of its destructive abundance in South Carolina, and the records of the Bureau of Entomology include a number of instances of its occurrence in wheat and other crops.

DISTRIBUTION.

In Van Duzee's catalogue the distribution of the species is given as from Carolina to Texas. Ball gives a further statement of dis-

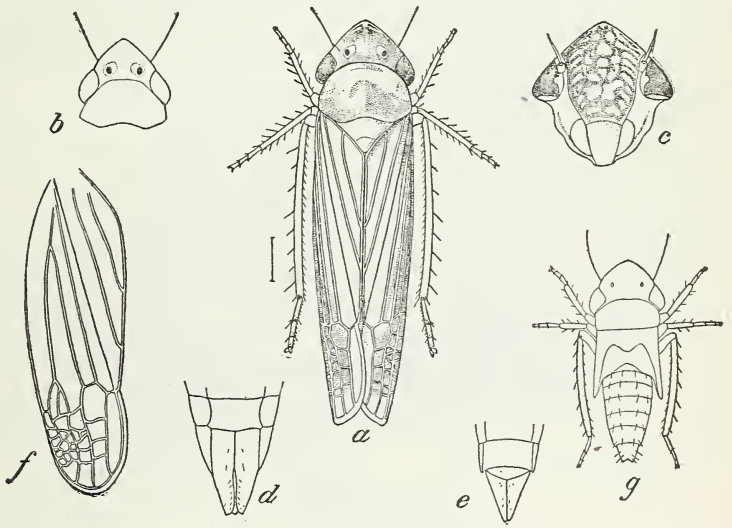

FIG. 2.—The yellow-headed leafhopper (*Drxculacephala reticulata*): *a*, Adult; *b*, vertex; *c*, front; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, supposed nymph from North Carolina. All enlarged. (Original.)

tribution covering South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, South Carolina, and Mexico, which, with the original description from Cuba, gives it a considerable range. Records in the Bureau of Entomology add Charlottesville, Va., as a more northern point, and during the past season it has been found in large numbers at Raleigh, N. C., Clemson College, S. C., and Decatur, Ga. There is one record of its occurrence in Lincoln, Nebr., which is the most northerly point from which we have found any indication of its presence, and so remote from other recorded localities that it may be based on an exceptional occurrence. If common there, it should also be found at intermediate points between this and Texas, but careful collecting has failed to discover it in Kansas. There is also a record for Fulton, Ky. I took it in Mississippi and also in Tucson, Ariz., in 1910. Prof. Ball has a record for Salina, Cal., and I took a similar form at Yuma, Ariz., in wild grass, but

this differs in having a triangular spot on the vertex. I did not find it at Knoxville, Tenn., although it certainly should have been there at the time I was searching for it (November 22, 1909), as other leafhoppers were quite active at the time. It appears, therefore, that there is a northern limit for the species, and this limit is not determined by any limitation of food plants, since the species occurs readily on various plants, a number of which are common at points farther north.

FOOD PLANTS.

The food plants of the species have generally been stated as wheat or oats, but since these records usually come from cases of excessive abundance during autumn it is very evident that they are based on migrations from adjacent fields. This was clearly determined during the present autumn by the finding of adults and larvæ in grassland adjacent to wheat fields at Raleigh, N. C., and at Columbia and Clemson College, S. C. At Raleigh it occurred in strips of bluegrass with other grasses; at Columbia and Clemson College particularly in Bermuda grass; and it was also found in Bermuda grass in fair abundance at Decatur, Ga. In Mississippi, Texas, Arizona, and California it was found most constantly in Bermuda grass and this is accredited as being one of its favorite hosts, but the records are too meager to permit the assertion that its range is coextensive with this plant. While observations are wanting, it may be very safely assumed that the eggs are deposited in some of these grasses of general distribution, that the larvæ develop upon these during early summer months, and that only after maturity do they spread from these to the wheat and oats.

DESCRIPTION.

This species is one which is very easily recognized, since it differs definitely from the other leafhoppers with which it is ordinarily associated. The structural features are shown in figure 2. The head is of a rather bright yellow or orange-yellow color, with two light spots on the vertex, including ocelli, and the forewings are light green. Beneath, including the legs, it is of a pale yellow color, the borders of the abdomen being slightly reddish.

A nymph which was referred to this species was found associated with adults at Raleigh, N. C., in the autumn of 1909. This was grayish, with orange patches on the sides of pronotum, and the same form associated with adults of *reticulata* has been sent to me from Dallas, Tex., so I feel confident that this is the nymphal form. A quite differently appearing nymph with more pointed head and a dark line along the middle line has been referred to this species by Prof. E. D. Ball, based on California specimens, but must, I think, be different or indicate a separation of the California form.

PROBABLY AN INTRODUCED SPECIES.

With the evidence at hand it appears quite certain that this species was introduced into the United States from a more southerly habitat. While the species might possibly have been overlooked by early collectors, it is too conspicuous a species where it occurs for this to be probable. Moreover the records would seem to indicate an advance toward the north since its first appearance in our Southern States. Its original description from Cuba, 1854, precedes any record here, while the early records refer to such southern localities as Texas and South Carolina, a distribution still holding in 1894, when Van Duzee's catalogue was published. In 1900, as recorded

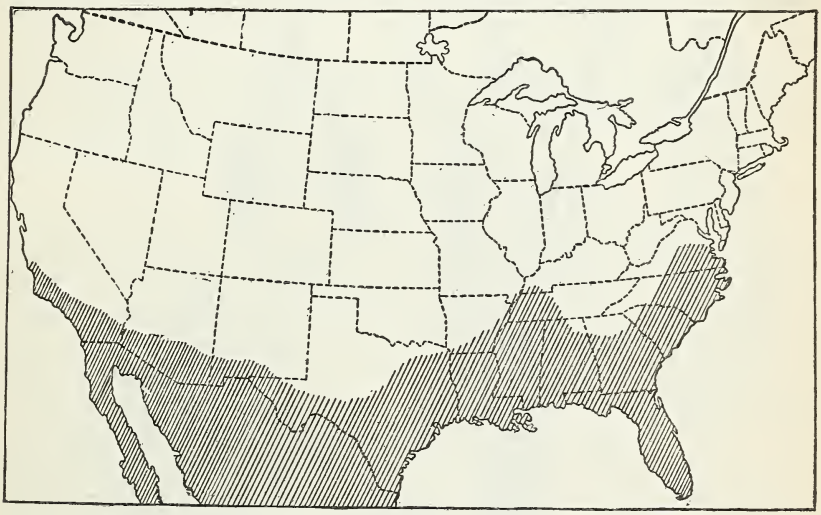

FIG. 3.—Map showing distribution of *Dræculacephala reticulata* in the United States. (Original.)

by Prof. E. D. Ball after he had made an exhaustive examination of records and specimens, the species had not spread north of the Gulf States and South Carolina. Now, however, it is found north, in the Atlantic region to middle Virginia (1906) and in the Mississippi Valley to southern Kentucky (Fulton in 1905). (See fig. 3.) That it is restricted climatically is evidenced by the slow progress made and its limitation to the warmer zone, the line of its northward distribution agreeing very closely with that of the cattle tick.

TREATMENT.

While additional knowledge concerning the place of egg deposition and development of nymphs and especially as to the number of generations during the year may furnish a better basis for the recommendation of measures for control, we may very safely conclude that the depredations on wheat and oats could be very materially lessened

by attention to the various grasses growing in the waste land adjacent to cultivated fields. Mowing and even burning over all such areas should very greatly reduce their numbers and if this is attended to before or soon after the appearance of wheat above the ground the attacks on this crop should be largely prevented.

Dræculacephala mollipes Say.

The species *Dræculacephala mollipes* (fig. 4) was described by Say in 1831 among the early descriptions of American insects and has been a very commonly observed species ever since. Nevertheless it seems to have received much less notice from the economic standpoint than it merits. It was mentioned by Dr. Fitch in his list of

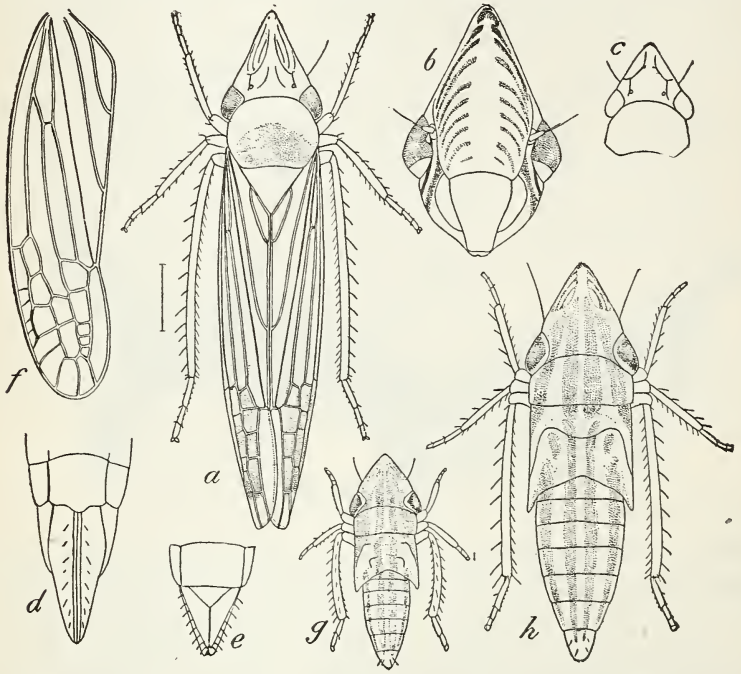

Fig. 4.—*Dræculacephala mollipes: a*, Adult from above; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, *h*, nymphs. All enlarged. (Original.)

insects in 1851, but without economic discussion; in 1884 Uhler gave a description in the Standard Natural History, saying that "the salt marshes of the Atlantic States furnish places of shelter for it where it may be found on weedy grasses in all stages from June to October." In 1890 Prof. H. Garman, in the Second Annual Report of the Kentucky Agricultural Experiment Station, describes it as a corn pest and speaks of it as abundant in several stages of growth on corn on low ground, generally concealed in the hollow formed by the partly unfolded blades. It evidently occurred in different stages, as he says that the recently matured specimens predominated

there, there being about half as many males and about the same number of young. This occurred at about the time the corn was about 2 feet in height (probably midsummer), as many as 20 leafhoppers being observed on a single plant in some of the fields. The area affected was not large, and the insects were not often found on corn on high ground. He also mentions that the species was affected by an epidemic disease, due to an insect fungus, *Empusa grylli*. In this connection it may be mentioned that Prof. Webster has a record of the occurrence of this fungus on this same species many years ago, the fungus being identified by Prof. Roland Thaxter at Harvard University. The writer called attention to the abundance of this species and gave a brief description of its economic status in Bulletin No. 22 of the Division of Entomology, U. S. Department of Agriculture, and in later years, 1891 and 1892, added some facts concerning its life history. In 1897 he published a brief summary of observations made by Mr. J. A. Rolfs on the method of egg deposition and the limits of broods.

DISTRIBUTION AND FOOD PLANTS.

This is one of the most widely distributed American species of leafhoppers, occurring throughout practically all of North America south of the strictly boreal portions of Canada. During the summers of 1909 and 1910 it was collected at every locality visited and usually in considerable numbers. A detailed record of the localities will include a list of practically every town where any collection of jassids has been made. Its range in food plants is also considerable, although it has apparently a distinct preference for certain grasses growing in the moister ground. It has been taken upon wheat, oats, rye, and barley, and the list of grasses affected includes many species. Bluegrass is apparently a less favored food plant, although it is often found in bluegrass fields, especially where other grasses are present.

DESCRIPTION.

The adult insect is of a bright grass-green color, quite slender in form, and when resting upon a blade of gress is very inconspicuous; in fact, can scarcely be seen unless it jumps or takes wing. The head is very sharply pointed, of a yellowish-green color, and is marked by several very delicate oblique lines. Beneath it is nearly black, the legs greenish, the wings a nearly transparent milky white; the length is about one-third of an inch for the female and about one-fourth of an inch for the male.

LIFE HISTORY.

It is rather curious, considering the great abundance and wide distribution of the species, that a full description of the nymphal stages has

not been published. This may be due in part to the very great abundance of the species and partly, perhaps, because the nymphs, while presenting evident characters, are not particularly striking in appearance; and partly, perhaps, it is due to general neglect of life-history studies for this group of insects. Egg deposition occurs in autumn and is at this time mainly confined to large-stemmed grasses occurring in the low ground or thoroughly moist locations, a selection which may be due to the more succulent character of the plant at this time or to a choice for the larger stems. The deposition in midsummer appears to be less restricted, and apparently the insects occur in the borders of the leaves as well as between the leaf sheath and stem. The series of eggs collected by Mr. R. A. Vickery, at Salisbury, N. C., which quite certainly belong to this species, were placed beneath the epidermis along the margin of the leaf, the inner end of the egg extending to the midrib. Owing to parasitism these eggs did not hatch, and the determination of the species is not absolute. Mr. Vickery, however, secured similar egg deposition in a leaf of corn when the insect was confined with this plant.

The newly hatched nymphs have not been observed, but nymphs of later stages have the characteristic shape of the adult, the head is sharply pointed, a little less so in the early stages, and becoming a little more acute with each of the molts. They are of a light-green or yellowish color, with four dorsal parallel stripes running very nearly from the front of the head to the end of the body. These stripes diminish gradually toward the end of the body, the two outer ones disappearing with the middle of the abdomen, while the two central ones continue to the end. The different molts agree quite closely in appearance, except in the development of the wing-pads. These in the last nymphal stages form the angles extending to the backs of the second abdominal segments.

There are clearly two distinct generations annually and a somewhat irregular occurrence of different stages during the autumn and winter owing to the survival of nymphs and adults. Hibernation seems to occur in all stages from the egg to the adult, although the great majority must pass the winter in the egg stage. Eggs hatching in the spring give rise to nymphs which reach maturity by the latter part of June, and these adults survive until about the 20th of August. The second generation of nymphs begins to appear about the second week in August and continues through September, appearing in October and November, although some individuals may be found as adult by the middle of September and others remain as nymphs until winter. These dates will vary somewhat with latitudes, and possibly a greater number of generations may be found in the southern localities, but no positive observations are on record for such regions.

MIGRATION.

Aside from the local migration which works in passing from field to field and the selection of attractive areas, the insect shows at times a distinct habit of migration at night. A number of instances are known where immense numbers have collected around electric lights, and this would seem to be associated with some general movement which brought them, perhaps the wind, as otherwise we can hardly account for the movement from their sheltered locations near the ground. Such migrations are observed during midsummer but, so far as I know, no instances of the migrations in late autumn have been observed.

REMEDIES.

Available remedies for this species are suggested in its habit of selecting the coarser kinds of grass for egg deposition in autumn, as it is quite possible to cut or burn such grass, and in this way the number of eggs that survive will be greatly lessened. The insect jumps very readily and may be captured in the hopperdozer quite successfully. It would also be open to treatment with the spraying machine when it occurs in fields which could be run over by such apparatus.

That the species is kept in check by parasites is evidenced by the fact that eggs are parasitized by one of the minute forms, probably Trichogramma, the species undetermined.

The occurrence of the fungus mentioned above may also be considered a distinct factor in the control of this species, although we can not suggest any practicable means of extending its operations. Doubtless the activity of predaceous species of insects and spiders plays a very considerable part in keeping the numbers down, and birds should be expected to take a larger proportion of these than of the smaller species.

DRÆCULACEPHALA NOVEBORACENSIS FITCH.

Dræculacephala noveboracensis Fitch is considerably larger than *Dr. mollipes*, and a little lighter in color, the shape of the head is different, being shorter and blunter, and there are two very distinctly marked dots at the tip. In its distribution it covers the larger part of the northern United States, from Vermont to Vancouver's Island, and south in the plateau region to Colorado, but its food plants are restricted to the coarse grass of low ground, and the common slough grass is apparently one of its favorite host plants. Adults are commonly taken during the latter part of June, through July, and from the middle of August until October, so we may safely assume that there are two generations annually and a life cycle corresponding closely to that of *Dr. mollipes*.

The nymphal forms have not been heretofore described, but were observed at Seattle in 1909, occurring on the coarse grasses upon which the adults were found. They are light green with pale wing-pads. The head is only bluntly pointed. The economic importance depends entirely upon whether the coarse grasses upon which it feeds have any economic importance. In some places these are used for hay or for covering to haystacks, while in some parts of the Northwest they are being used quite extensively in the manufacture of mats and various kinds of furniture. In any case it would be a more difficult species to control than *mollipes* on account of the rank growth of the grasses upon which it occurs. The main opportunity for attack would seem to lie in a cutting of the grass in autumn after egg deposition, which would serve to destroy the eggs or remove them from the locality where they could be of injury.

Diedrocephala coccinea Forst.

Diedrocephala coccinea Forst. is a bright colored species, one of the handsomest of all jassids, about the size of *Dræculacephala mollipes* but differing in the shape of the head, which is rounded in front. The elytra are marked with brilliant blue and red stripes. The nymphs are yellow with dark wing-pads.

There are two generations annually, and nymphs of the first generation occur during May and June, and adults may be found about the middle of June until the latter part of July and for the autumn generation during September and October. The nymphs, therefore, must develop during the periods from the latter part of June until late August. Apparently the winter is passed in the egg form, and nymphs should occur in the spring from the hatching of eggs earlier in the season. The species is much more common in woody localities and usually is to be swept from the undergrowth of grass and weeds. It occurs, however, in localities where grass is a large admixture of the vegetation, and it seems quite certain that the grasses constitute a part of its food supply.

The Bog Leafhopper.

(*Helochara communis* Fitch.)

The bog leafhopper (*Helochara communis* Fitch) is an extremely abundant species throughout the larger part of the country, and may be found in practically every locality in the United States where suitable food plants occur.

It is a small, dark-green species, about one-fourth to one-third of an inch long, the head and prothorax longer than the rest of the

body, and the surface, especially of the head and pronotum, distinctly pitted. It appears somewhat like *Dræculacephala mollipes*, but the head is much less pointed and the color is a darker green. (See fig. 5.)

The life cycle has not been worked out in detail, but nymphs evidently belonging to this species may be found during midsummer in the low, swampy grasses where the species is evidently abundant. The food plants consist of swamp grasses, and the insect is found in greatest abundance upon the small, fine grasses of the genus Juncus, but so far as known it is not restricted to any particular species. It is found only in rather moist locations, never on the high, dry ground. It is therefore of much less economic importance than some of the

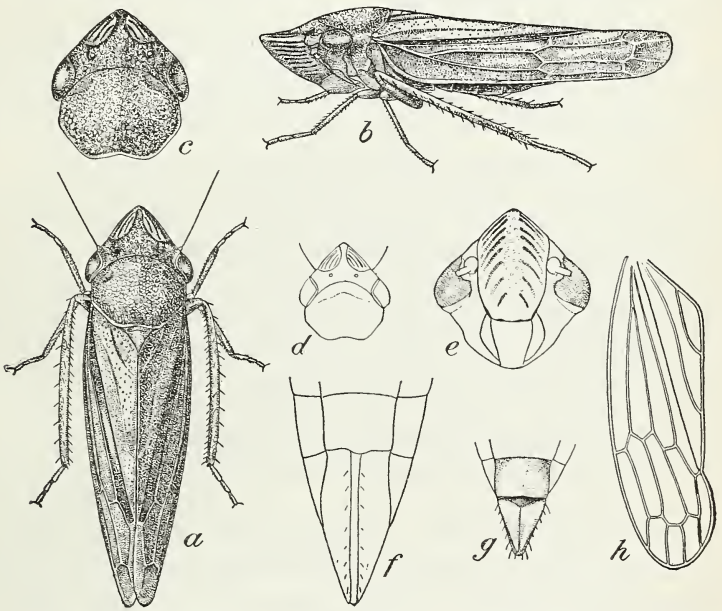

FIG. 5.—The bog leafhopper (*Helochara communis*): *a*, Adult; *b*, side view; *c*, head and pronotum of female; *d*, head and pronotum of male; *e*, face; *f*, female genitalia; *g*, male genitalia; *h*, elytron. All enlarged. (Original.)

other species. So far as these lowland grasses have a forage value it is of course to be counted, and since it occurs sometimes in enormous swarms it may cause a considerable reduction in growth. The actual effect of its presence is seldom observed, as the grasses on account of their abundant moisture keep their color in spite of the drain caused by the insects. The species is one which could not be easily controlled, since the methods of treatment available for pastures and meadows are not so applicable in the low ground where these forms occur. Probably the spraying methods would be most effective, as these could be used where the hopperdozer would not work to advantage.

Gypona octolineata Say.

Gypona octolineata Say is a rather general feeder but it occurs so commonly in grasses and in grain fields that it must be reckoned as one of the grass-feeding species. It is a large insect, the size varying from a third of an inch to one-half inch in length and the color is light yellowish green with a series of dark yellow or orange lines running lengthwise from the head and thorax. Nymphs, which are commonly met with in fields, are very broad and flattened, much flatter than even the adult, which they resemble, in fact, so that they may be easily recognized. The head is narrowed in front of the eyes, the front portion of the head being extremely thin, and the antennæ are quite thin.

The general color is green and the surface of the body is covered with a rather dense fine hair, the fully developed nymphs of the last nymphal stage being broader and shorter and of a darker green than the other stages, and there being two brown spots on the inner angle of the wing-pads. There are two generations annually, the life cycle in general consisting of the appearance of the nymphs by the middle of June and the completion of these nymphal stages about the middle of July. The adults of the midsummer generation appear from about the 1st of July until about the middle of August and the second nymphal generation from the latter part of August through September. The adults of the autumn generation appear in September and remain until the middle or latter part of October. Presumably eggs are deposited in autumn, as no adults have been observed in early spring. The species is extremely widely distributed and has been given a considerable number of different names, based either on geographic distribution or upon the variations which may occur in some locality. A quite prominent form has a distinctly scarlet color in autumn, but otherwise seems not to differ from the ordinary form. Its food plants are so varied that it is difficult to suggest any ways by which it may be controlled, based on food plants or locations of egg deposition, and it seems necessary to leave it to the control of natural enemies which, on the whole, appear to keep it fairly within bounds.

Gypona bimaculata Spang.

Gypona bimaculata Spang. is a very large leafhopper, the largest, in fact, of any which is known to attack grains and grasses in the United States, and it is a species quite generally distributed throughout the northern portion of the country, occurring from New York and Pennsylvania westward through Ohio, Indiana, Illinois, Minnesota, and Iowa to the west. It was described as *bipunctulata* in 1887 by Woodworth, but no account which considered it as an economic

species appeared before a statement of its life history in the Proceedings of the Iowa Academy of Science in 1897. The females are a light, bright green, very robust and thick bodied, the thorax very broadly covered, the ocelli small. There is a distinct black dot on each side of the pronotum about halfway from the middle to the margin; also a minute dot near the base of each wing cover, just back of the angle of the pronotum. It has been known to occur on a variety of grasses, more especially the lower growing, coarser grasses of swampy or boggy places. Whether it has a restricted habit for the deposition of eggs or whether the nymphs are confined to any particular grass is not determined. There is only one generation, and the adults appear about the middle of July and remain until the latter part of September. Full-grown nymphs have been taken in Iowa from prairie grasses in early July. Evidently the eggs are deposited in autumn and survive the winter, presumably upon some of the coarse grasses on low ground.

TETTIGONIA BIFIDA Say.

The species *Tettigonia bifida* Say has not figured as an economic insect, but on account of its wide distribution and its abundant occurrence, in many instances, it seems worthy of more recognition than has been given to it. Its range of food plants is limited, the insect being found almost exclusively in or near wooded pastures, where it occurs especially in bluegrass and may be found as adult during a number of weeks in late summer. Its general life history was worked out in connection with the study of grass-feeding leafhoppers in Iowa some years ago, but aside from that no description of habits or life history has been given.

The adult insect is about one-fourth of an inch long and of a deep greenish color and with circular alternate bands of black and white on the head and pronotum, and the forewings have seven distinct stripes, the dark one being forked near the middle. The adults are noticed early in July and become distinctly abundant by the middle and latter part of the month, after which they diminish in numbers and disappear early in autumn. Egg deposition occurs evidently during July or August and nymphs appear during these months. The nymphs when first observed were about half the length of the adults and fully as broad, with the surface of a powdery-white appearance. The head is large, broad, and deep, almost round in front. The eyes are dark, the wing-pads broad and short. The abdomen is somewhat keeled along the dorsal central line. These nymphs are distinctly different from those of any other members of the genus and may be easily recognized. While the species is not anything like so abundant as some of the other forms, it has been collected in rank bluegrass in such numbers as to give an estimate of 50,000 per acre.

Hecalus lineatus Uhl.

Glossocratus lineatus Uhler, Bul. U. S. Geol. and Geog. Surv., vol. 3, p. 464, 1877 (♀).

Glossocratus fenestratus Uhler, Bul. U. S. Geol. and Geog. Surv., vol. 3, p. 464, 1874.

Hecalus lineatus Uhler, Osborn and Ball, Proc. Iowa Acad. Sci., vol. 4, p. 188 (♀) (♂).

Hecalus lineatus Uhl. is one of the largest of the grass-feeding species. (See fig. 6.) The female measures 12 mm. to the tip of the exserted, attenuate ovipositor. The head is 2.5 mm. long by 2 mm. broad, slightly narrowed in front of the eyes, widening immediately to a spoon-shaped tip, which is thin and slightly reflexed. The body color is bright green, with four equidistant parallel lines extending

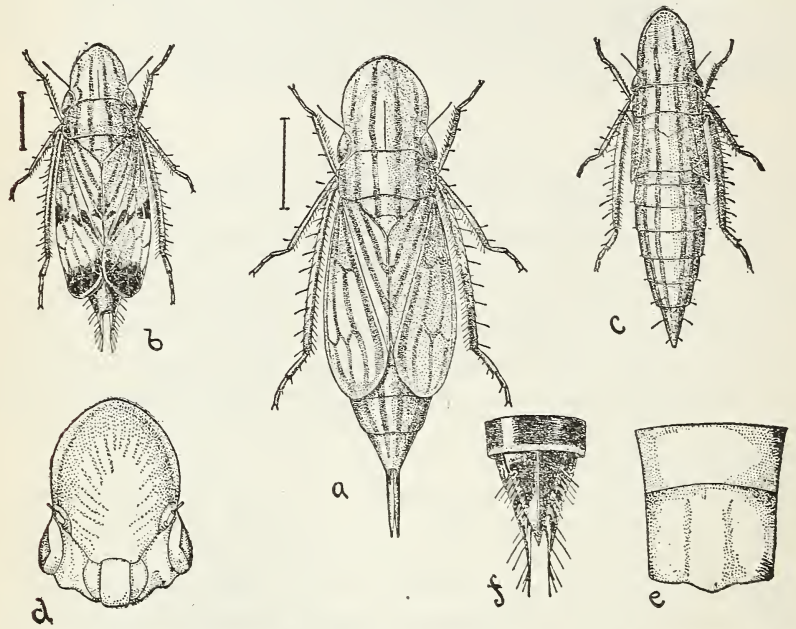

Fig. 6.—*Hecalus lineatus: a*, Female; *b*, male; *c*, mature nymph; *d*, face; *e*, last ventral segment of female; *f*, male genitalia All enlarged. (After Osborn and Ball.)

over the head, thorax, and scutellum; the nerves of the elytra and ovipositor are orange-red.

The males are quite different from the females in appearance, and were described by Prof. Uhler as *Glossocratus fenestratus,* and were long regarded as a distinct species. They are much smaller, measuring scarcely 8 mm. to the tip of the style-like pygofers. The head, thorax, and basal part of the elytra are marked as in the female but the ground color approaches orange. The apical half of the elytra and the abdomen are quite different. There is a narrow black band just back of the middle of the elytra and a broader terminal one;

between these is a hyaline area with a small, curved, dark spur extending in on the center of the outer margin. The abdomen is annulated with black, and the terminal segment, valve, and attenuate plates are black.

The nymphs are narrow, elongate, closely resembling the female in color and in the stripes which extend along the abdomen.

The nymphs were found at Ames, Iowa, on an isolated patch of slough grass (*Spartina cynosuroides*) early in August. They were then nearly full grown.

At Ames, Iowa, the adults were taken in coitu in the middle of August, and from then on through September were found in some numbers on the limited patch where their food plant occurred.

It is highly probable that the eggs from the autumn generation are deposited in the stems of slough grass before the middle of September, in which case the ordinary time of mowing would be an effectual remedy, and would account for the rarity of the species in cultivated areas, or in sections annually overrun by prairie fires.

The species has been collected at many different places in the country but never in large numbers. Its paucity in collections, however, is not to be considered as proving its rarity, as it is not so easily captured as many of the jassids unless its particular habitat is known.

It had been reported from Kansas and New Jersey, including only a few specimens in all, and there was a specimen in the Van Duzee collection from New York, and one specimen had been taken at Ames and another at Batavia, Iowa, up to the time that its life history was studied at Ames.

At Ames, Iowa, it was found in considerable numbers and observations recorded in the Proceedings of the Iowa Academy of Sciences, volume 4, 1897. Since then it has been recorded for a number of localities and during the summer of 1909 I collected it in South Dakota at Brookings in June, at Ada, Minn., in early July, and at Devils Lake, N. Dak., late in July. In all probability it may be found over much if not all of the territory covered by the coarse slough grass (*Spartina cynosuroides*), which is the only plant on which larvæ have been recorded and which may be the only host plant for the species.

The Shovel-nosed Leafhopper.

(*Dorycephalus platyrhynchus* Osb.)

The shovel-nosed leafhopper (*Dorycephalus platyrhynchus* Osb.) is one of the most remarkable of the grass-feeding jassids (see fig. 7), being peculiar both in its appearance and habits. It is very seldom seen, since it closely resembles the plants on which it occurs and moreover does not jump readily as is the case with most of the leafhoppers. The records made in Iowa, where its life history was worked out, are

the principal ones so far appearing, but it is listed also from Nebraska and a specimen from Wellington, Kans., in the bureau collection evidently belongs here.

"It is single brooded, the adult appearing about the middle of May and continuing in decreasing numbers until the end of July. During the last week in May and the first week in June the eggs are deposited; the female selects a spot about 2 inches above the base of the first or second leaf from the bottom; having selected the spot apparently with much care, she takes her position head upwards, legs placed

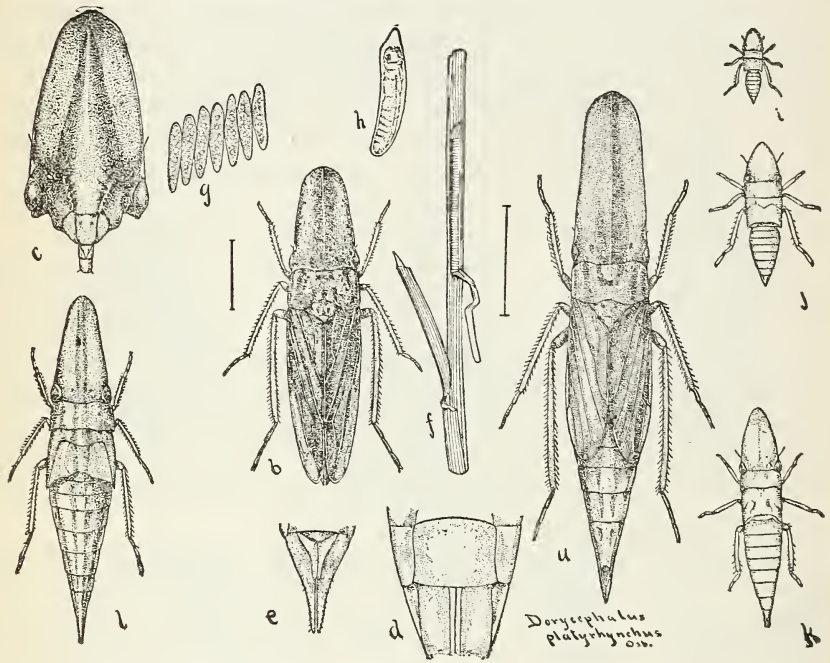

FIG. 7.—The shovel-nosed leafhopper (*Dorycephalus platyrhynchus*): *a*, Female; *b*, male; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, eggs in grass stem; *g*, eggs; *h*, egg, more enlarged and showing developing nymph; *i*, *j*, *k*, *l*, different stages of growth of nymph. All enlarged. (After Osborn and Ball.)

close together and tarsi clasping the stem; then, raising the body the length of her legs and curving the abdomen upward, she unsheathes the ovipositor from the pygofers and brings its tip down against the grass stalk, pointing backward slightly from the perpendicular; she then moves slowly around the stem, keeping the body parallel with it and the guides pressed firmly against it until they catch under the edge of the encircling leaf sheath; having done this they are gradually forced under the sheath, usually extending almost half way round the stem. As they are gradually forced in, the abdomen straightens and then hollows until, when the ovipositor is fully inserted, the abdomen is curved down, and the pygofers are pointed upward and backward at more than a right angle with the guides. Having reached this position she works slowly backwards, opening the sheath

downward with a peculiar sawing motion alternating with a slight pause for the deposition of an egg.

"The eggs are one and one-half millimeters by one-third millimeter, cylindrical, gradually tapering from a point near the head back to an obtusely rounded tip; the anterior end is cut off obliquely from one side and rounded from the other, coming to an obtuse point. They are deposited in a continuous row, from 30 to 50, side by side, curving slightly around the stem with their heads toward the edge of the sheath, from which they are distant about one-third the circumference. The time occupied in actual deposition is from 20 to 40 minutes, but the selection of a location and the catching of a sheath edge often occupy several hours.

"Although the eggs were deposited through a period of two weeks or more they apparently all hatched at about the same time; the time evidently depending considerably upon favorable conditions of temperature and moisture, for, up to July 2, no larvæ had been observed either in the cages or in the field. On this afternoon the air was very oppressive, and remained so until cleared by a heavy thunder storm during the following night. On the morning of the 3d they were observed just emerging from the eggs in the cage, and examinations showed that they had hatched in the field also. The earliest deposition from which they were observed to issue on this date was made May 23, and the latest on June 9, while the majority were deposited June 4 and 5. This gives from 26 to 38 days, with an average of about 1 month, as the period of incubation.

"The freshly hatched larvæ have shorter and blunter heads than the adults, and are much more active, but within a week or two the head has elongated, and it has adopted the sluggish habit of the adult.

"Upon hatching, the larvæ immediately arrange themselves along the base and margins of the broad leaves parallel to the veins, where they remain stationary for weeks at a time, so closely resembling the rust spots and discolorations occasioned by their punctures that the chance of their detection is slight, or they ascend to the head, where they conceal themselves so effectually among the glumes and sheaths upon which they feed that one might carefully examine a head and pronounce it free from them, only to find, on shaking it violently, that it contained a whole colony. Here they stay until the head ripens in September, when they descend to feed on the second growth and the surrounding grasses until winter, when they crawl into the thick clump of the Elymus and hibernate, appearing again in early May and changing to pupæ. From then on until the middle of the month they feed on any green plant, near enough to be reached, crawling at last to the top of some blade of grass and issuing as adults over 10 months from the time of hatching from eggs.

"This species, in common with the others which occur in long and short winged forms, are usually very thick, where they occur at all; but the eggs, being deposited only upon the Elymus, they are limited in their range to a radius of a few feet at most from their host.

"They have been observed to feed upon the heads of *Elymus virginicus* indiscriminately with those of *canadensis* where the two grasses are near together, or near enough for migration, and in the spring, when the larvæ were large and abundant and the grasses small and inconspicuous, they were found upon everything occurring within a reasonable distance of the host."

Parabolocratus viridis Uhl.

Parabolocratus viridis Uhl. is a species of wide distribution, occurring from Massachusetts to northwestern Montana, and has been

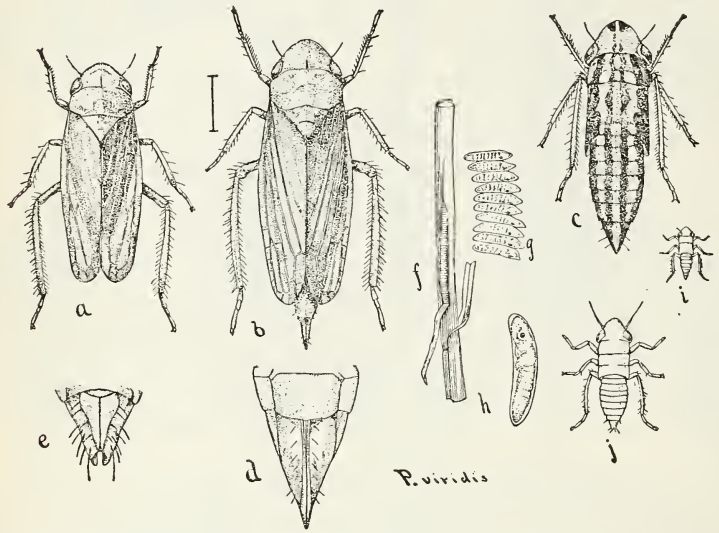

Fig. 8.—*Parabolocratus viridis:* *a*, Male; *b*, female; *c*, nymph; *d*, female genitalia; *e*, male genitalia; *f*, eggs in stem; *g*, eggs, enlarged; *h*, single egg, still more enlarged; *i*, *j*, young nymphs. All enlarged. (After Osborn and Ball.)

collected by many different observers, though usually in small numbers. So far as definite records go, it develops only on the wild oats (*Stipa spartea*). Except for collections extending its known range, scarcely any information has been gained since the publication of the life-history details in the Proceedings of the Iowa Academy of Sciences in 1897, by Osborn and Ball, and I can not do better than quote directly from the account published at that time:

"The adult female is about 7.5 mm. long by 2 mm. broad, with a parabolically curved, thin-edged vertex and a stout abdomen, attenuated posteriorly and extending beyond the rounding elytra. The males are smaller and have the vertex shorter and more obtusely pointed. The abdomen is smaller and does not extend beyond the narrow and nearly parallel-margined elytra. (See fig. 8.)

"They are both of uniformly deep-green color above, somewhat lighter below, with a narrow band under the sharp vertex, and the eyes dark; the exserted tip of the ovipositor orange-red.

"The first brood of adults appeared the first week in May and remained until the middle of June, disappearing gradually. They feed principally upon the leaves, usually about the middle, feeding on either side and either end up, with equal ease.

"The eggs are deposited during the last of May and the first week in June. The females, usually selecting a position just above the first leaf base and invariably placing themselves head downward, exsert the ovipositor and insert it under the flap of the sheath, gradually working backward up the stalk for a distance of 2 inches or more and depositing from 70 to 120 eggs within an hour.

"The eggs are 1.23 mm. long and 0.25 mm. broad, cylindrical, of nearly uniform size, curving considerable around the small stem.

"The larvæ appeared the last week in June, giving an incubation period of 15 to 20 days. Upon bursting the egg-case the larvæ crawl partly out from under the sheath and remain quiescent in this position for an hour or two when, becoming suddenly active, a flock of small larvæ may be seen ascending the stalk and distributing themselves upon the leaves, while a row of freshly shed skins, with the abdomen still remaining under the sheath, their tips scarcely free from egg-shells, explains the cause of the delay.

"They require about a month to develop, maturing during the latter part of July and the first of August, the adults remaining until the middle of September.

The host plant is variously estimated, in some instances being considered a troublesome, dangerous weed, in others as a valuable forage plant. In parts of North Dakota especially I was informed that the stock raisers prize it and cut and feed it regardless of the stiff barbs. It appears earlier than some of the other grasses, thus supplying early grazing, and if cut early before the development of the long barbs, must make a good quality of hay. Early cutting has also the advantage of destroying the eggs of this leafhopper and its scarcity may be due to such destruction—mowing closely between the 10th and 16th of June in Iowa, and relatively later farther north will destroy the first brood of eggs and dispose of the barbs, giving a later growth of nutritious grass free from jassids. Should adults appear in numbers in August, a second mowing in the latter part of this month should dispose of the second brood of eggs.

The Sharp-nosed Leafhopper.

(*Platymetopius acutus* Say.)

The sharp-nosed leafhopper (*Platymetopius acutus* Say) is one of the species that has an almost universal distribution throughout the United States, and while it has never been reported as occurring in

such numbers as some of the other species, it can hardly be overlooked in a discussion of the species of economic importance. It was recognized and described by Say nearly a century ago and has had quite frequent mention in scientific papers, but no discussion of habits or description of early stages until 1897, when it was treated in a paper on the species occurring in Iowa.

The adult insect (fig. 9) is distinguished by a remarkably long, pointed head, and narrow, elongate face, a brownish-gray color, with very numerous round white points on the wings and with a row of black cross-veins on the border. It is about one-fifth inch in length. The larvæ are similar to the adults in shape, having a very much elongated head, narrowing to an acute point, and when full grown they are about one-sixth inch long. They are characterized particularly by a broad light stripe along the back, passing from the tip of

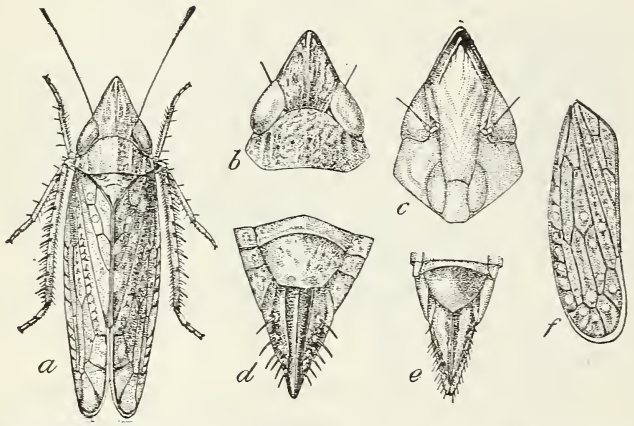

FIG. 9.—The sharp-nosed leafhopper (*Platymetopius acutus*): *a*, Adult; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, elytron. All enlarged. (Original.)

the head across the thorax, where it widens, and narrowing on the base of the abdomen and expanding on the central part and again on the extreme tip. This stripe is bright red on the center and shades into a creamy white on the margin. It is sometimes divided on the abdomen into two spots, one on the central portion and another at the tip. A black stripe extends along each side the entire length of the body, the stripes meeting below the tip of the head. It includes numerous minute white spots underneath a creamy white.

The young are first noticed during the latter part of May and mature before the end of June, the adults beginning to appear by the middle of June and continuing until the middle of July, the nymphs of the second generation appearing in July and maturing in August, while the adults of this second generation are found from the middle of August until into October. Apparently these lay eggs in autumn, which survive the winter to hatch in spring. The young are found in grassland, but more commonly in shady situations, and the adults are to be found quite generally distributed on different kinds of

grasses or on low vegetation and appear to be general feeders. They have not been determined as restricted to any single kind of grass as a host plant.

The Yellow-faced Leafhopper.

(*Platymetopius frontalis* Van D.)

The yellow-faced leafhopper (*Platymetopius frontalis* Van D.) is a much darker species than the *acutus*, ranging from dark brown to distinctly black with a broad border and lemon-yellow face. The forewings are marked with numerous round, white spots. In size it is somewhat shorter but more robust than *acutus* and the head is not so long or so sharply pointed. (See fig. 10.)

The young, which resemble the adults in shape, have a broad, light-yellow or creamy colored stripe occupying the large part of the back, but leaving a marginal dark border somewhat like that of *Deltocephalus inimicus*, but in this species the marginal stripe expands on the head in front of the eye. The life history of the species is similar to that of *Platymetopius acutus*, the nymphs appearing about the last of May and being found through the most of June, and adults occurring from the middle of June on nearly through July. The nymphs of the second generation appear by the middle of July and occur until the latter part of August, while the adults of this second generation begin to appear about the middle of August and are found abundantly through September into October, presumably depositing eggs, which survive the winter, as adults are not to be found late in autumn or early in spring. This species seems to prefer shaded locations, as it is usually found much more plentiful in the vicinity of thickets or coarse weeds, but it occurs also in rather rank grass, clover, etc., in pastures or meadows. The nymphs are swept from the undergrowth of grass and weeds.

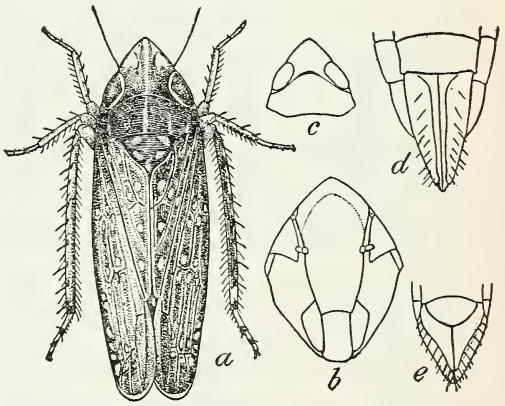

FIG. 10.—The yellow-faced leafhopper (*Platymetopius frontalis*): *a*, Adult; *b*, face; *c*, vertex and pronotum of male; *d*, female genitalia; *e*, male genitalia. All enlarged. (Original.)

The species has a very extended distribution in the United States, ranging from eastern Canada to New York and to Illinois, Iowa, and Kansas, and it occurs in many cases in considerable abundance, so that it may properly be considered as of economic importance.

While perhaps not so destructive as to require particular discussion of remedies, it may be said that it would be affected by the same treatment as that applied to the other grass-feeding species, but would not be destroyed quite so commonly in the treatment applied to the short grass of pastures or to closely mown fields.

Platymetopius cinereus Osb. and Ball.

The species *Platymetopius cinereus* Osb. and Ball has not been observed for anything like the extent of range or abundance noted for the other species mentioned, but in a few instances has been found to occur in considerable numbers. It is a smaller and lighter colored species than *acutus*, the female being only about one-sixth inch in length and the male still smaller. The larvæ are distinguished from those of *acutus* by the absence of the red color and the dorsal stripe, and from those of *frontalis* by the much more elongate form.

The nymphs of this species have been observed early in June, but nearly full grown, so that they must have been developing during the latter part of May, and by the middle and latter part of June they are replaced by adults, which are found in decreasing numbers until after the middle of July. Nymphs of a second brood are noted by the last of July, and remain in abundance up to the middle of August. These again are replaced by adults which begin to appear by the second week in August and continue on through September. The species is known from Iowa through Nebraska and Kansas to Arizona. It appears to develop especially on three different kinds of grasses, *Andropogon scoparius*, *Bouteloua hirsuta*, and *B. curtipendula*, the latter two species probably being its most common hosts. It is therefore more particularly of importance in the plains region, where the wild grasses form an important part of the forage, and so far as known need not be considered as of importance to the ordinary cultivated grasses of the Mississippi Valley or the Eastern or Southeastern States.

The Inimical Leafhopper.

(*Deltocephalus inimicus* Say.)

The *Deltocephalus inimicus* of Say (figs. 11, 12) is one of the most widespread and injurious species among the leafhoppers, but nevertheless it has received comparatively little notice in economic literature. It was first described in 1831 by Thomas Say, who states in connection with the description that when in the larval state this species is said to depredate on the roots of wheat. "Several specimens were sent me by Prof. Green, in the year 1822, who received several from a farmer in Virginia." This would place the recognition of the species as an injurious pest as far back as 1822, nearly a

century ago, but the next mention of it from an economic standpoint appears to have been in 1884, when Prof. Forbes speaks of it as occurring in corn and also injuring wheat in connection with two other species of leafhoppers which he described in detail. Dr. Fitch merely mentions it in his list published in 1851, but does not seem to have recognized its economic importance. Other notice of it does not appear until 1890, when, in a report to the Division of Entomology, I called attention to its abundance and its destructiveness in Iowa in connection with other insects. I also described the general appearance of the larva in 1891 and published some details of the life history in 1892 and 1893. Also, in Bulletin 19 of the Iowa Agricultural Experiment Station, I described the treatment for it, especially with the hopperdozer. Prof. F. M. Webster, in 1896, mentioned the life history, etc., in Bulletin 68 of the Ohio Agricultural Experiment Station.

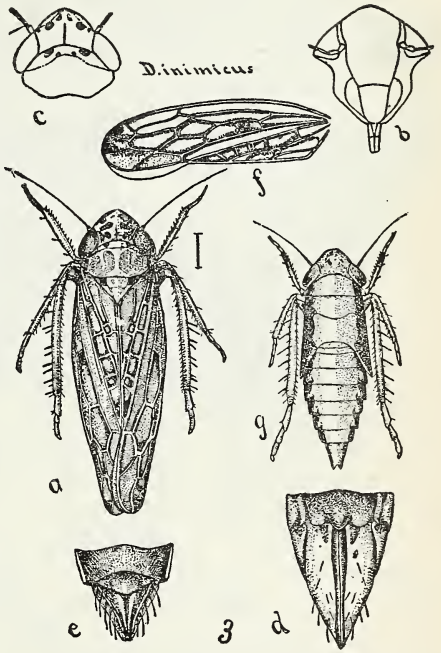

FIG. 11.—The inimical leafhopper (*Deltocephalus inimicus*): *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, elytron; *g*, nymph. All enlarged. (After Osborn and Ball.)

DISTRIBUTION.

The species is one of very wide distribution in America (see fig. 13) and appears to be confined to this country. Van Duzee, in his catalogue, credited it to Canada and the United States west to the Rocky Mountains, but later records indicate its general occurrence all the way from Maine to Washington State and south at least to Tennessee and southwest to Kansas.

In the summer of 1909 I found it on grass at Ames, Iowa; in the Missouri Valley in grass, timothy, wheat, and alfalfa; in South Dakota at Vermillion, and at Brookings in wheat, bluegrass, timothy, and wild grass; in North Dakota at Fargo, June 25 to 28, full-grown nymphs and adults, in pasture, especially an old brome-grass pasture and a timothy-clover pasture. At Ada, Minn., July 2, in wheat fields and grass; at Dickinson, N. Dak., July 8, in alfalfa; at Mammoth Hot Springs, Yellowstone Park, July 14, in irrigated plat (?); at Bozeman and Missoula, Mont., July 15 and 16, on grass; at Moscow, Idaho, and Pullman, Wash., on timothy, festuca, and alfalfa; at Kalispell,

Mont., July 24, on grass; at Williston, N. Dak., in wheat, oats, alfalfa, and clover, and in brome grass of second-year planting; at Devils Lake, N. Dak., on bluegrass and timothy, and at Grand Forks, N. Dak., on bluegrass (lawn) and in a stubble field, including red-top and clover; at Castalia, Ohio, August 13, abundant in bluegrass and volunteer wheat, and at Toledo, Ohio, August 27, in bluegrass pasture and field of Hungarian grass; at Columbus, Ohio, September 1 and 16 and October 8, in bluegrass, and at Akron, Ohio, September 11, in stubble field (wheat), including timothy and clover; at Wooster, Ohio, September 14, in clover, alfalfa, and low-ground pasture and in plat of mammoth millet; at Urbana, Ill., September 28, in a timothy and clover field; at Lafayette, Ind., October 4 and 5, in bluegrass pasture, in alfalfa, on volunteer wheat, in clover, and in

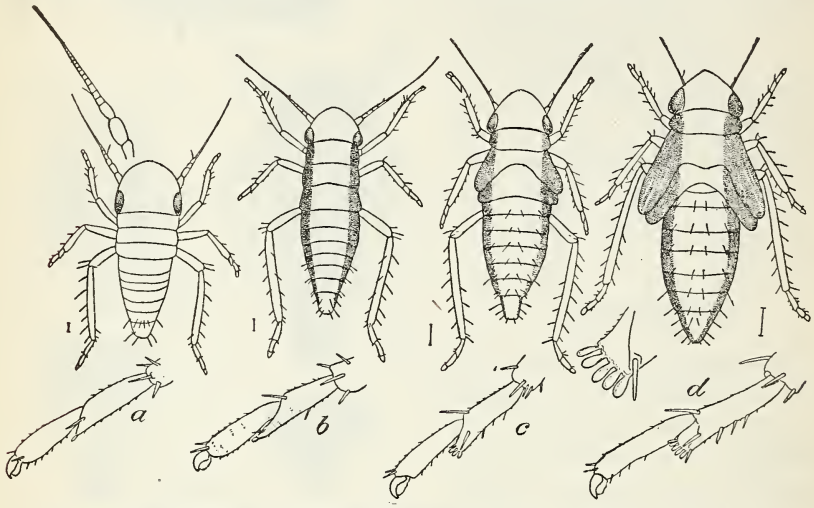

FIG. 12.—The inimical leafhopper (*Deltocephalus inimicus*): Nymphal stages; *a*, newly hatched; *b*, *c*, *d*, later stages, the details of tarsal appendages shown below. All enlarged. (Original.)

a wheat plat, newly started; at Fort Benjamin Harrison near Lawrence, Ind., October 6, in stubble field, including mixed grasses, clover, and other vegetation; at Hamburg, N. Y., October 20, in wheat, new growth, and at Valencia, Pa., on November 2, in new growth of wheat; at Harrisburg, Pa., November 5, none in wheat but a few in grass; at Reading, November 6, in grass and a few in wheat; at Newark, Del., November 9, in wheat (a few) and in grass; at College Park, Md., November 11, in grass and only a few in wheat, oats, and barley; at Arlington, Va., November 12, in grass and wheat; at Washington, D. C., November 13, in grass; at Knoxville, Tenn., November 22, on bluegrass, orchard grass, and fall barley. In June (22–24), 1910, it was found abundant at Mackinac Island and Sault Sainte Marie, Mich., both in wheat and grass. Nearly all taken were

in the nymphal stages, ranging from those recently hatched to mature, but a few adults also were secured.

Its particular habitat is throughout the country where bluegrass is the common pasture grass, and this is, perhaps, its favorite food plant. So generally distributed is it that it is almost impossible to sweep over any patch of bluegrass anywhere from Maine to Washington without finding representatives of this species among the leafhoppers that are captured. Throughout most of this territory it is usually the most abundant of the species taken, and in many cases it far exceeds all other species in numbers. In the statement of relative abundance, written by Mr. V. L. Wildermuth in another

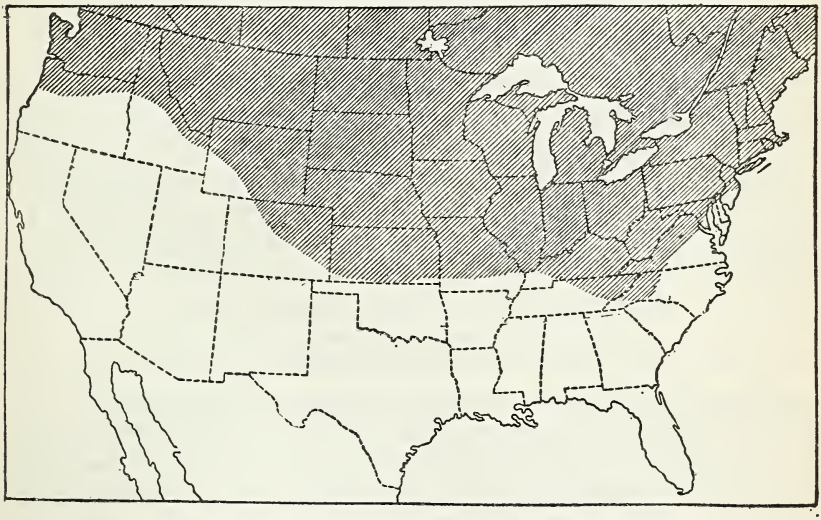

FIG. 13.—Map showing distribution of *Deltocephalus inimicus*. (Original.)

place (pp. 14-15), it will be observed that this species may comprise about nine-tenths of the numbers captured. While bluegrass and timothy are the more common food plants, the species has a wide range and has been observed on wheat, oats, corn, millet, rye, clover, alfalfa, and a considerable number of wild grasses of the plains region. This general occurrence on different food plants makes it possible for the species to survive in almost any locality, and it is thus given abundant opportunities to migrate to any favorable crop which may grow within a reasonable range.

LIFE HISTORY.

(Figs. 11, 12.)

Although the larva was mentioned by Say in his original description, no study of the life history seems to have been made until 1892. General descriptions of the different stages are given in Bulletin No. 30 of the Bureau of Entomology and in Bulletin No. 20 of the

Iowa Agricultural Experiment Station. The eggs are deposited in the leaf or stem, especially beneath the epidermis of bluegrass, and cause very minute, blisterlike swellings. These, for the winter generation, remain until spring and hatch, for the latitude of Iowa, in the latter part of April and early May, there being some variation according to season. This generation matures by the latter part of June or early in July and adults occurring early in July deposit eggs which hatch within a few days, producing nymphs of the second brood in the latter part of July. These mature by the latter part of August, and adults are usually encountered from this time on until winter, although scattering nymphs are likely to occur during the autumn months. No proof, however, is available of a definite third brood for the season, and eggs deposited by adults in autumn survive the winter to renew the cycle the following year.

During the growth of the nymphs five distinct stages have been observed, the first of which, the newly hatched nymph, is rather short, with a very prominent head and a small abdomen, and without clear markings. The second stage differs in a more elongate form of body and a definite black border along the sides of the thorax and abdomen. The third stage differs from the second only in the appearance of the wing-pads, and from this stage on through the fourth and fifth stages the change consists merely in a greater intensity in coloring and relative increase in size of the wing-pads. At the end of the tibia of the hind legs there is a peculiar microscopic spatulate structure that occurs in varying numbers from the newly hatched nymph to the adult form. In the specimens studied and figured there were for the first instar one, for the second instar two, for the third instar three, for the fourth instar five, and for the adult insect five. The adults are gray, with dark brown or blackish markings. A very constant feature is the presence of three pairs of black spots, one on the vertex, one on the pronotum, and one on the scutellum. The length is about one-fourth of an inch.

The molts occur at intervals of seven or eight days in examples observed in rearing cages and in some instances the development from the newly hatched nymph to the adult occurred in 32 days. The time of incubation for some eggs has been determined as not longer than 17 nor less than 10 days. This, however, was confined to jars, and it is possible that under outdoor conditions the rate of development may be more rapid. A record by Prof. Webster of observations on the development of the species adds some further information and may be introduced here for comparison.

Several years ago, on November 11, a number of adults were placed on young wheat plants that had been reared indoors, and hence were free from affection by insect attack. The females began at once to oviposit in the tissue of the leaves, and the young could be observed developing within the eggs, especially after they had become well advanced. Young were especially noticeable just prior to their emerging by their eyes being jet black. The young molted a few days after hatching, and, so far as I

could observe, but twice afterwards. December 22 one of the first individuals to appear molted for the last time, and on the following day adults were out in numbers. It will be observed that 41 days were required for the development of the insect from egg to adult. It is not unlikely that the species hibernates in the egg state in the leaves of grass, though it would seem probable that it may also live over as adults. My wheat plants were kept growing in glass tubes, probably an inch and a half in diameter, and in a temperature of probably not far from 70° F. (Webster, Ohio Agr. Exp. Station Bul. 68, p. 43, 1896.)

TREATMENT.

There is not much to be added to the discussion of general treatment, as this species is one of the most widely distributed and is open to every remedy which has been advised for the leafhoppers in general. The fact that it is primarily a grass insect and that it attacks wheat, oats, and other grains incidentally, makes it possible to restrict its injuries to other than grass crops by attention to the fields adjacent to such cultivated crops. The burning of grass along the sides of the field, in fence corners, or along roadsides would in a large degree protect wheat fields from the fall migrations. The species is readily caught in the hopperdozer, and in pastures or permanent meadows where burning is not considered desirable this or the application of an insecticide by spraying is probably the most available remedy.

The Black-faced Leafhopper.

(*Deltocephalus nigrifrons* Forbes.)

The black-faced leafhopper (*Deltocephalus nigrifrons* Forbes) is an abundant and very widely distributed species, occurring in a very perplexing number of variations, so that it has received several different technical names. It was first described by Prof. S. A. Forbes from specimens found depredating in wheat and oats, but no details of life history were given and, apparently, no detailed study of its habits or distribution. Since then little has been done in the way of working out its habits and, aside from a publication of a record of its occurrence on different food plants and a description of the lymphal stage in 1907 by Osborn and Ball, very little has been published.

It is one of those perplexing aggregations which are the despair of systematic workers and which are excellent examples for the evolutionist, since the different variations run off into such extreme forms as to indicate the possibility of incipient species. We need not consider in detail the systematic problems, however, as apparently for this species these do not have any very great economic significance. If it were a question of the economic importance of separate varieties this question might be much more essential. So far as determined, however, all of the forms will migrate readily from one plant to another and consequently no restriction corresponding with these variations is to be considered.

DISTRIBUTION.

The distribution of the species, as here limited, covers a large part if not the entire territory of the northern and eastern United States, as material has been examined all the way from New York to Washington, D. C., and south to South Carolina and Georgia, and west to New Mexico. In this distribution there seems no particular limit to the different varieties, but any of them may occur within the different territorial limits.

FOOD PLANTS.

It has a considerable range of food plants, but there is apparently a quite distinct preference for the annual grasses, such as foxtail or panic grasses and others, but it migrates very readily from these into wheat, oats, and other cereals and also occurs very commonly in bluegrass and timothy, especially after the withering of the annual grasses upon which it has fed earlier in the season. On this account it is one of the most troublesome forms occurring in fall wheat and oats, since it has developed in great numbers upon early grasses and with the failing of these as a food supply is forced to migrate, and this migration, coming with the appearance of the young and succulent plants of wheat and oats, affords the most attractive bait.

DESCRIPTION AND LIFE-HISTORY NOTES.

The adults (see fig. 14) are to be recognized by the rather short vertex, the margins of which are plainly rounded, and especially by a distinct row of black spots which lies next the border of the upper part of the head and bends down alongside the eyes in front. Of these spots there are four on the upper part between the ocelli, usually one on each ocellus, and two on each side between the ocellus and base of the antennæ. Other spots may occur with greater or less distinctness on the upper part of the head, but are too variable to constitute good characters for recognition. The face is usually marked with numerous black bars; sometimes it is entirely black or with only a few light streaks on the lower portion. The upper part of the body, the thorax, and the wings vary greatly in intensity of color, sometimes being very light, occurring without any distinct markings, and sometimes presenting distinct dark-brownish markings, especially along the veins of the forewing. The forewing presents a peculiar diversity in the development of the cross veins, some examples presenting two distinct veins, while others, apparently identical in every other respect, are wanting in the hinder one of these cross veins. These two forms not only agree in other respects but are evidently derived from nymphs which are idistinguishable.

The nymph is rather broad and resembles in characters the *Deltocephalus flavicosta*, but is slightly narrower and not so distinctly

marked. It is yellowish in color, has two black dots on the margin of the upper surface, and often two oblique dashes on the disk. The last nymphal stage further presents very distinct spots—those on the front margin of the wing pads and a number on the hinder end of the disk which are more or less distinctly arranged in transverse rows. The nymph is not very readily separated from that of *Athysanus exitiosus*, but the latter species has black spots on the head farther down upon the front. The nymphs of this species appear in early summer and the adults are usually to be found in numbers by the first of July. These adults deposit eggs and the nymphs from these develop during July and August, and adults appear in September and are to be found on into October and November and in localities farther south will be taken in numbers as late as during November and early December. In fact, they seem to remain active until severe cold weather forces them into inactivity.

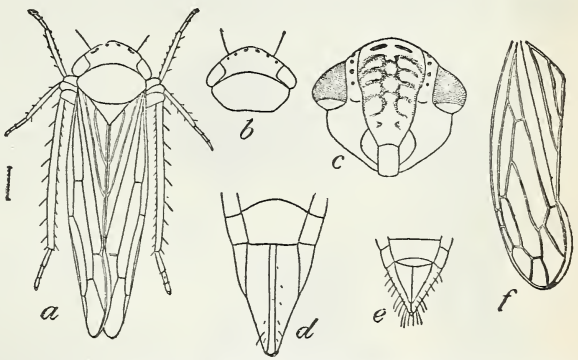

FIG. 14.—The black-faced leafhopper (*Deltocephalus nigrifrons*): *a*, Dorsal view; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, wing. All enlarged. (Original.)

MEANS OF CONTROL.

The method of control for this species may be based directly upon the migratory habit of the species and especially upon the fact that it develops so largely in the field grasses which are either worthless or noxious in character. In many places the mere elimination of foxtails and panics which grow along the borders or in neglected cornfields would greatly reduce the numbers of this pest, and in some instances it would be entirely practicable to burn the borders of fields, where such grasses are beginning to wither, in time to kill the hoppers which may occur there. In the Southern States, especially where fields are often interspersed with strips of uncultivated ground, the burning or even close mowing of such strips would doubtless be of considerable service in preventing injury to fall wheat and oats. Additional knowledge concerning the actual method of deposition of eggs may add to the possible measures for control.

DELTOCEPHALUS SONORUS Ball.

The species *Deltocephalus sonorus* Ball is one of the *nigrifrons* group, but is uniformly smaller and more slender, and the spots on the border of the vertex are quite constantly arranged so that there is a small

one near the tip of the vertex and a larger round one above the ocellus, usually quite conspicuous. The color is pallid and the veins are usually but slightly apparent; the wings extend beyond the abdomen; the length is about 4 mm.

This species occurs upon the annual grasses and has a very general distribution, especially in the southern part of the United States, from Florida to southern California. It sometimes appears in great abundance, as shown by the collections of Mr. C. N. Ainslie in Texas and New Mexico, and by the writer in California, and may be a distinctly economic species passing from annual grasses or weeds to cultivated crops. The most evident method of control, with our present knowledge of the species, is the elimination of the host grasses during the early part of the summer.

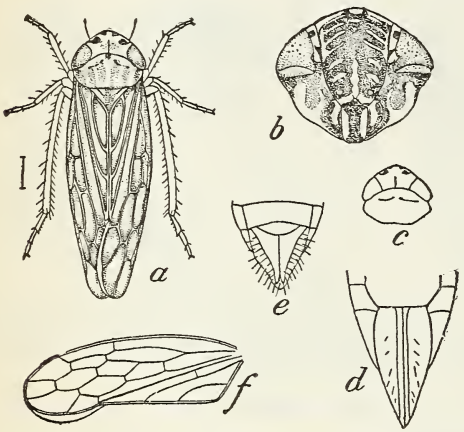

FIG. 15.—*Deltocephalus fuscinervosus: a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing. All enlarged. (Original)

DELTOCEPHALUS FUSCINERVOSUS Van D.

Deltocephalus fuscinervosus Van D. is a southwestern form closely related to *D. nigrifrons*, but with darker coloration above and a more complete fusion of the spots on the vertex. (See fig. 15.) The genitalia are quite similar, and it is probable that the two forms stand as divergent branches from a common stock.

This form occurs abundantly in the wild grasses of southern California and is found as far north as San Francisco.

DELTOCEPHALUS CONFIGURATUS Uhl.

Deltocephalus configuratus was described in 1878 by Prof. Uhler from specimens which were collected in one of the geological surveys through the Rocky Mountains region, but no intimation was given of its economic importance and no statement of any such importance occurs until the report on the work of Iowa species in 1896. At that time it was recognized as important, as it was taken in great abundance in both the nymphal and adult forms in grasses. The species has a wide distribution throughout the northern part of the United States and probably in the southern portion of Canada. Records from various sources show it to occur from Mount Washington, N. H., through New York and northern Ohio, Illinois, Iowa, the Dakotas,

Wyoming, and Montana. At Tower City, N. Dak., it was reported in 1901 and 1905, evidently occurring in abundance in grasses, as collections included large numbers of both males and females. In New York it was stated by Van Duzee to be "a common meadow insect from May to August, but in the year 1904 I did not find it in any numbers except at Hamburg, although I collected at a number of different points in that State. Probably, however, my collections were made a little too late in the summer to find it at its greatest abundance. In 1909 I found it quite common at Brookings, S. Dak., June 20 and 25, especially in wild grasses, and at Fargo, N. Dak., it was the most abundant species for this and the succeeding month in an old pasture of brome grass. It occurred at the Mammoth Hot Springs, Yellowstone Park, Wyo., July 9, on native grasses.

It is one of the largest species of the genus Deltocephalus and is easily recognized by the broad blunt head as well as by the peculiar structure of the genitalia. (See fig. 16.) The last ventral segment of the female ends in a narrow black process divided at the tip, and the male plates are large, broad, and obliquely truncate. The forewings are usually longer than the abdomen, but vary in length in different individuals.

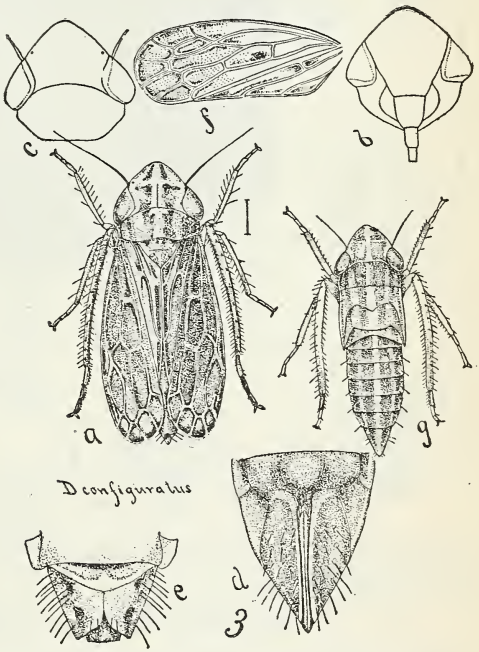

FIG. 16.—*Deltocephalus configuratus: a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. All enlarged. (After Osborn and Ball.)

The nymphs have a broad head, the front of which is rounded and marked with brownish bars. They are pale brown above, with three indistinct stripes and a row of dots just within the narrow light border on each side of the abdomen. The full-grown nymphs were first taken in Iowa early in May along with adults that had apparently just issued from the nymphal stage, and within two weeks the nymphs had all matured and adults were very abundant throughout June and a few occurred in early July. At the time the observations were made in 1906 the field in which they were made, and which was under observation throughout the whole season, was mowed June 25; the only specimens indicating a second generation were some half-grown

nymphs occurring July 16. While this record would indicate two generations each year, it indicates also the fact that an early mowing in May coinciding with the time at which the species occurs in the egg form in the stems of grasses would effectually control it. Other species of the genus, the egg deposition of which occurred at a different period, were not so completely exterminated as this one. The results in this case, however, would seem to show that mowing, at a time when the eggs occur on the plants, may be a very effectual method of reducing the numbers of this species, which has a definitely limited period of egg deposition. It would, of course, be open to the same

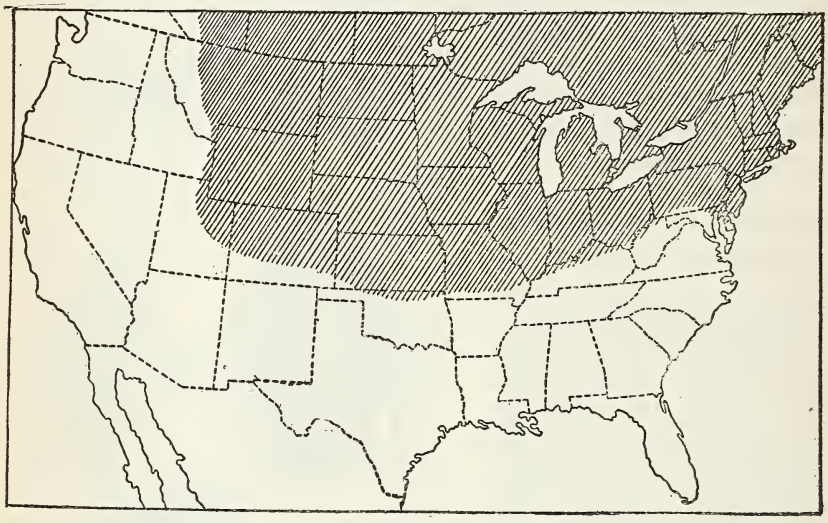

FIG. 17.—Map showing distribution of *Deltocephalus affinis*. (Original.)

methods of destruction by hopperdozer, spraying, and burning as any of the other species.

DELTOCEPHALUS AFFINIS Gillette and Ball.

The species *Deltocephalus affinis* has been discussed under the names *debilis* and *melscheimeri* in earlier articles, but it is first mentioned as an economic species in a report of the Division of Entomology, United States Department of Agriculture, in 1890. It was an extremely abundant and apparently destructive species in Iowa during a number of years when it was observed in that State. It occurs in greatest abundance in bluegrass in lawns and upon pastures or meadows, showing a distinct preference for open and sunny situations rather than shaded locations. It was abundant in both wheat and grass at Sault Ste. Marie, June 23 and 24, 1910, mainly in the adult stage.

DISTRIBUTION.

It has a very extensive distribution (see fig. 17), having been reported under various names from the New England States and

throughout the northern United States and southern Canada and is evidently a form that was reported by Dr. Wm. H. Ashmead under the name *harrimani* from Alaska (report of Homoptera, Harriman Alaska expedition).

DESCRIPTION.

The adult insect is of a light gray or brownish-gray, often pale, but varying so much in color that it has been many times described under different names. It is nearly one-sixth of an inch long and is to be separated from *D inimicus* by the absence of definite black spots on the head and thorax and by the slightly smaller size. The head, too, is a little more distinctly pointed. (See fig. 18.) The most positive characters are found in the genitalia, the last ventral segment of the female being short, nearly straight on the hind border, while the male valve is very much enlarged and convexly rounded, almost covering the plates, the tips of which appear as slight projections beyond its hind border.

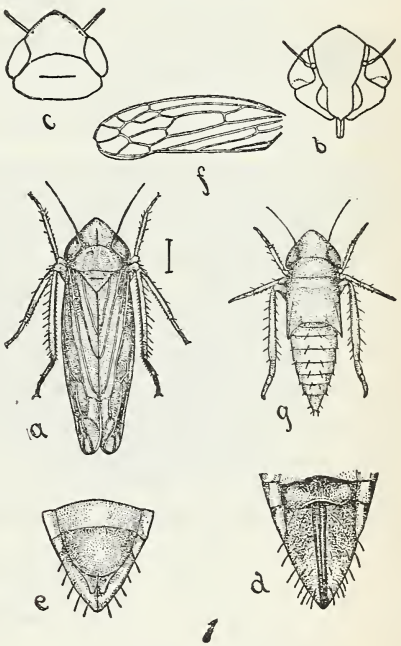

FIG. 18.—*Deltocephalus affinis: a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. All enlarged. (After Osborn and Ball.)

The nymphs are of about the same form as those of *inimicus*, but differ distinctly in that the body is uniformly light yellow without the black lateral border which is characteristic of *inimicus*. The head is bluntly angled in front and in the later nymphal stage the wing-pads expand in a rather sharp angle back to the second abdominal segment.

LIFE HISTORY.

The life history of the species has not been determined with complete accuracy and is difficult to establish because of the irregularity with which the different generations appear and the overlapping of adult and nymphal stages. From observations in Iowa it was believed that there might be three or possibly four generations each year and the designation of the broods so far as they could be determined showed adults from the middle of May until the last of June; nymphs

from the first week in June until the middle of July; adults, again, from the first week in July through August; nymphs through August until the middle of September, and again adults from the middle of September through the season. The evidence is therefore very strong that eggs are deposited in autumn, survive the winter, hatch in early spring, and developing as nymphs during April or early May reach the adult condition, as observed above, by the middle of May.

REMEDIES.

So far as observation or experiment goes the most satisfactory treatment for this species is the use of hopperdozers or sprays during the early part of the season so as to reduce the numbers and prevent injury during the latter part of the summer. From the observations in Iowa it appears that the most effective dates for the use of hopperdozers would be from May 25 to June 10, again from July 15 to July 25, and again, if the insects are still abundant, about August 10. As the eggs are quite certainly in the leaves or stems of dead grass during the autumn, winter, and early spring, it would seem almost certain that burning over the grassland where practicable would have a very positive effect upon this species. Of course this is not possible in some cases on account of the amount of green vegetation that would prevent the burning, and in other cases, if the grass is too dry, there would be danger of killing out the plants. Perhaps the best results would come from burning while the ground is frozen and at times when the upper portion of the grass is dry enough to carry fire.

Say's Leafhopper.

(*Deltocephalus sayi* Fitch.)

Say's leafhopper (*Deltocephalus sayi* Fitch) is another widely-distributed species occurring in abundance in practically all kinds of grasslands throughout the northern United States, but showing a preference for bluegrass in woody pastures. It seems to have little preference for upland or low ground except as the grass becomes dry in midsummer, when it will be found gathering more particularly in shady places or where extra moisture permits the grass to remain more succulent. It has been recorded or observed for localities all the way from New Hampshire to the Rocky Mountain region with records as far south as North Carolina, Kentucky, and Kansas, and it probably has a distribution farther south at least along the Appalachians. (See fig. 19.) Its numbers are sufficient to make it a considerable pest in pastures and meadows where it occurs, although it does not have the extreme abundance noted for *D. inimicus* or *D. affinis*.

The adult insects (see fig. 20, *a*) are small, robust creatures with a rather distinctly pointed head and with the fore-wings broad and

rather short in many cases, exposing the tip of the abdomen beyond the ends of the wings. They are dark brown in color with distinct light markings and a fairly distinct band across the wing-base and again back of the middle of the fore-wings. They are a trifle more than one-eighth inch in length.

The nymphs (fig. 20, *g*) are rather slender and have a quite distinctly angular head colored much as in the adult, but the arrangement of the markings is different. There is a narrow middle line of white extending from the tip of the head to the end of the abdomen, where it widens and nearly covers the tip. There is a broad stripe extending along the side from the eye back to near the tip of the abdomen and an indistinct narrow one from the inner margin of the eye broken by white spots, one on the hind edge of each abdominal segment; there

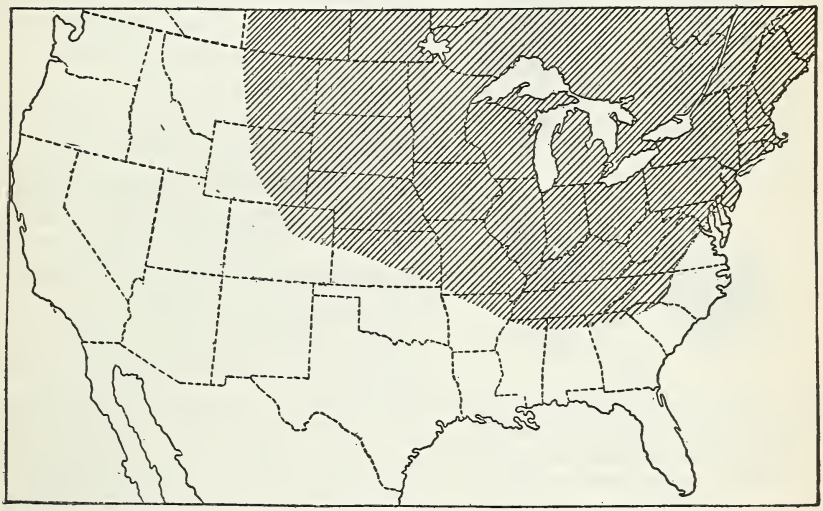

FIG. 19.—Map showing distribution of *Deltocephalus sayi*. (Original.)

is a second row of dots midway between the first and the marginal stripe on each side. In Iowa the nymphs were first found in small numbers on upland prairies the second week in June. They were full grown and probably somewhat later than the average as the adults had been taken during the first week of June and occurred in great numbers in watered pastures by the middle of the month. The adults were abundant from that time on through the season, but nymphs were again found on July 11 about half grown and full grown by the latter part of July along with fresh-looking adults. Nearly full-grown nymphs were again seen on the 5th of September and later in the month they were becoming rare while the adults were still plentiful. The adults probably survived some time after egg deposition, so that there is a continuous occurrence of adults to be noted throughout all of the latter part of summer. Egg deposition probably occurs in early October, as dissected females showed no signs of eggs the latter

part of the month. While broods are not very definitely separated it would seem from the observations made that the first brood of nymphs occurs from May until the early part of June, the adults of this brood from the last week in May until the middle of July, and the second brood of nymphs from the last week in June until the first week in August, while the second brood of adults, beginning to appear about the middle of July, extends through August; a third brood of nymphs, appearing first about the middle of August, develops during August and September, and the third group of adults, beginning to appear in early September, survives on through October. From this life history it is obvious that it will be difficult to fix upon any time at which mowing of the grass would be distinctly effective in exterminating the species, consequently we must depend upon the direct treatment of hopperdozers or sprays or the effect of general rotation of crops as the principal means of control.

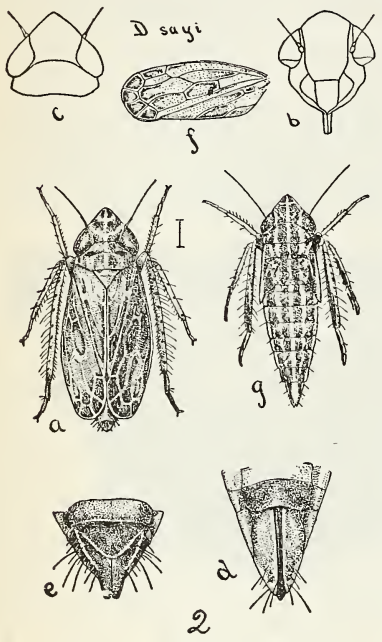

FIG. 20.—Say's leafhopper (*Deltocephalus sayi*): *a*, Adult; *b*, face; *c*, vertex and pronotum; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, nymph. All enlarged. (After Osborn and Ball.)

This species has been found to be quite extensively parasitized by the small hymenopterous parasites of the family Dryinidæ. At one time at Cedar Point, Ohio, as many as about 20 per cent of the individuals collected showed the presence of the little external sacks of these parasites. Doubtless they constitute an important factor in keeping the species reduced in numbers throughout its range.

The Destructive Leafhopper.

(*Athysanus exitiosus* Uhl.)

Athysanus exitiosus was first given definite recognition as a destructive pest in the report of Prof. J. H. Comstock for the Department of Agriculture, in 1879, and in connection with his report there is given a technical description of the species by Prof. Uhler.

While it seems impossible that the injuries of the insect should have escaped previous observation, it is probable that they were referred to some other insect or that the insect itself was not connected definitely with this kind of injury.

This report mentions damage during the previous winter to grain in western South Carolina, parts of North Carolina, and Georgia,

with evidence that the leafhopper occurred in immense numbers and did great injury to the crops.

Prof. Comstock's account is so brief and covers the conditions at the time so well that it will be best to quote a few paragraphs of his article entire:

So many alarming reports were received during the course of the winter as to the extent of damage, that it was deemed necessary for me to visit the infested locality, which was accordingly done on my return from Florida about the first of March. In company with Mr. C. R. Jones, of the Charlotte Observer, I inspected several fields in the vicinity of Charlotte, North Carolina, and found that the accounts had not been exaggerated. In one infested field of ten acres, belonging to Mr. Geo. King, there was hardly one plant left to each square rod of ground. The diseased appearance most common in the wheat fields was a wilting of the outer leaves of the plant. Professor Uhler informs me that the customary method of injuring grass or grain is to pierce and suck the juices from the midrib of the leaf, and this method of work I have been able to confirm by an examination of leaves taken from the infested wheat. In a few cases I found the wilted leaves merely cut off at the base; this must have been done by some other insect.

In the wheat fields of Mr. W. W. Rankin the leaf-hoppers were at work in large numbers. There was observable on this plantation a most exact line between the eaten and uneaten portions. Instead of spreading themselves indiscriminately over the field, or half eating a patch here and there, they ate the wheat down to the ground as they progressed. In an eight-acre field six and one-half acres were utterly destroyed, while on the remaining acre and a half the crop was almost uninjured. It was, however, being rapidly destroyed. Here was apparently a good opportunity to watch them at their work, but it was impossible to do much on account of their extreme shyness, as they would fly upon the least disturbance. Professor Uhler has observed them about the time of oviposition resting on the midrib of a blade of grass or grain, with the head pointed toward the base of the leaf. The eggs are usually laid in the stems of grasses near the ground, judging from the known habits of allied species. The young hoppers when hatched are of almost precisely the same appearance as the old ones, except that they lack the wings. The time occupied in attaining full growth probably does not exceed a month, so that there are several broods a year.

Many erroneous opinions were given concerning the nature of this insect. Many considered it to be some form of the Hessian fly. Others, without attempting to name it, called it the fly of the maggot, which lives near the roots of the wheat. I was also informed by Mr. Jones that a theory was prevalent to the effect that the leaf-hoppers had spread from the cotton fields from the fact that similar insects were found in the dried cotton bolls. An examination, however, showed the cotton-boll insects to be a Psocus, often found in such situations, and which belongs to an entirely different order from the leaf-hoppers, the Neuroptera.

The great damage done the past winter was probably a result of the extreme mildness of the weather. Under ordinary circumstances the leaf-hoppers are kept in winter quarters and many are killed by cold weather. The present winter has been so warm, however, that they have been able to feed and reproduce continually. Moreover, the crops being in a young and tender condition, the effect of the work of the hoppers was infinitely more marked than it could ever be at any other season of the year. Under the ordinary conditions, then, of a moderately cold winter the ravages of this pest are not to be feared.

From our present knowledge of the habits of the leaf-hoppers, their injuries in mild winters in the more southern portions of the wheat belt will be very difficult to control. The only remedy which I have been able to suggest in answer to the urgent inquiries of the South Carolina farmers has been that used for the destruction of the allied leaf-hoppers on the grape vine, namely, carrying lighted torches through the infested

fields, at night, or building bonfires at different points. These insects are readily attracted by light, and great numbers will without doubt be destroyed. One or another of the trap lanterns mentioned in that part of this report relating to the cotton work could without much doubt be used to advantage if a number were mounted on posts in different parts of the fields.

A green leaf-hopper somewhat larger in size has recently been received from Laurens, S. C., with an account of its injuries similar to those given of the destructive leaf-hopper. It was identified by Professor Uhler as the *Diedrocephala flaviceps* of Riley, a species which did much injury to grain in Texas in 1876.

Other records in the Bureau of Entomology show it to have occurred as follows:

March 23, 1880, reported swarming in immense numbers at Cookesburg, S. C., on wheat fields.

January 29, 1880, specimens from South Carolina with statement that they were doing great injury to wheat.

March 20, 1880, from Laurens, Laurens County, S. C., and from the Charlotte Observer, Charlotte, N. C.

February 20, 1882, from Atlanta, Ga., in great numbers on oats about Albany, Ga.

October 8, 1895, from Columbia City, Ind., "Myriads of them occur in a wheat field."

February 28, 1880: "When disturbed, they fly 3 or 4 feet and alight. The wheat looks stunted and shriveled. Many of the outer leaves are yellow. Ten acres were perfectly bare, not one spear per square rod, wheat sown from the 15th of September to the 1st of December. Leafhoppers first observed this year Christmas time. Later at Charlotte, N. C., in wheat sown November 15, saw that something was the matter with the wheat a week or 10 days later—i. e., as soon as wheat was up. It has been an unusually warm winter, which had probably allowed the insect to increase."

May 4, 1889, from J. G. Barlow, Cadet, Mo., larvæ, which no doubt belong to this species, with report of much damage to timothy meadows which were sown the previous fall.

March 22, 1890, Athens, Ga., injurious to young barley.

November 15, 1897, Hawley, Okla., infesting wheat, a few of the blades turning yellow.

DESCRIPTION.

The adult insect (fig. 21, *a*) for this species is about one-sixth inch in length, the males being somewhat smaller than the females. The color varies from dark, nearly black (especially in individuals from the Southwest) to grayish-white, the wings especially being almost transparent but showing very distinct dark veins. The head is broad and the body tapers quite distinctly to the tip of the wings, the widest part of the body being about one-fourth the distance from head to end of body. The eggs which were secured by dissection from an adult female are about 1 mm. long and 0.05 mm. thick, distinctly enlarged near one end and tapering to a rather distinct, blunt point at the other end. They are placed in the leaves or between the leaf-sheath and stem of the plant.

Prof. Comstock states that the young hoppers when hatched are almost or precisely the same in appearance as the old ones except that they lack the wings. There is, however, a slight difference in the position of the spots on the head and in the proportion of the parts

of the body, the head appearing considerably larger in proportion, and this proportion decreases as the young insect develops. The head is broad, the eyes prominent, and there are two distinct black spots on the front portion of the head surrounded by a lighter circle, and the body is marked with grayish dots both on the thorax and abdomen. As the nymph grows the wing-pads develop at the sides and in the final stage extend back over the base of the abdomen.

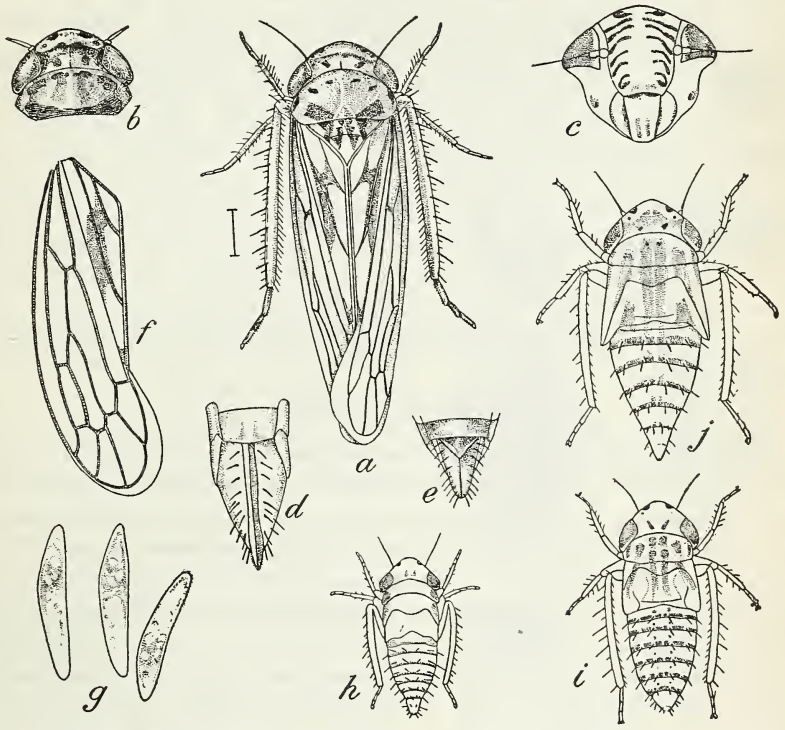

FIG. 21.—The destructive leafhopper (*Athysanus exitiosus*): *a*, Adult female, dorsal view; *b*, head and pronotum of male; *c*, face of female; *d*, female genitalia; *e*, male genitalia; *f*, wing; *g*, eggs dissected from female; *h*, *i*, *j*, three stages of nymphal growth. All enlarged. (Original.)

These characters may best be seen in figure 21, which includes three nymphal stages.

LIFE HISTORY.

The adults of this species are found until late in autumn or even on warm days in winter, and in the Southern States doubtless remain active during a large part of the winter. It is probable, however, that the majority lay eggs there in late autumn or early spring. The nymphs develop in spring and mature individuals are to be found early in summer, and there are quite certainly two broods for all of the Northern States and probably three or more for the southern portion of the country. The exact limits of broods is not known and can not be readily determined because there is so much irregularity in the

time of occurrence of the different forms, in that adults and young of all stages may be found at almost any time of the year.

DISTRIBUTION.

The distribution of the species was given by Van Duzee in 1894 as from Maryland to Florida and west to Colorado and Texas, but later records have extended this distribution so as to cover practically all of the United States and portions of Mexico and the West Indies. During the year 1909–10 I found it in abundance at almost every point where collections were made from the Dakotas to Washington and in the Eastern States from New York to Georgia, and Southwest it swarmed in almost every locality from Texas to California, being one of the most abundant species met with in collections from grass, wheat, oats, and fall rye. It is quite probable that this is a southern species that has spread over the northern United States in comparatively recent times, but it is now well established. Evidently it is to be considered one of the most important of all the jassids when its wide distribution and possibilities for multiplication are taken into account.

MEANS OF CONTROL.

The control of the species is a matter somewhat difficult for grasslands, although it can be captured in the same manner as other common leafhoppers, but the attacks on grain, especially upon fall wheat, rye, barley, and oats, ought to be very readily prevented by attention to the adjacent grasslands at the proper time in midsummer or early autumn before the appearance of the growth of the fall grain crops. If it is appreciated that these jassids develop entirely during the summer months in the pastures or meadows or grasslands adjacent to the cultivated fields, it will be seen that the proper basis of treatment is to attack them in these adjacent fields. While they may not appear remarkably abundant or seem to cause great injury in the grasslands, they are, nevertheless, draining the crop extensively, and when these plants begin to ripen or become less succulent the tendency is for the leafhopper to migrate into the grain fields. Since they fly very readily they accumulate in large numbers in the grain fields and consequently produce the very marked injuries that have been described. The treatment of the grassland will depend largely upon what the nature of the land is and its importance as pasture or meadow. If practicable, it may be sprayed or treated with the hopperdozer, but for rough land, especially that which is not of importance for pasture, probably the most available method would be to burn over as completely as possible in September or at about the time that the grain crops are planted. Of course some of the adults might escape by flights, but at this time a large number of the insects would be in the nymphal stages and unable to fly, and consequently

unable to escape from the fire. The method suggested by Prof. Comstock, of utilizing lights to which they are attracted, may prove of considerable advantage, but there has been no careful experimental test of the effect of this kind of treatment.

Athysanus curtisii Fitch.

The species *Athysanus curtisii* Fitch is one that is quite widely distributed throughout the northern part of the United States and, while not occurring in such enormous numbers as some of the related species, is a very constant factor, breeding especially in woodland pastures and living upon several different species of grasses. It was described by Dr. Fitch in 1851 and evidently recognized by him as having economic importance although he gives no details of its life history. It was discussed, among other species of grass-feeding leafhoppers, in the bulletins of the Iowa Agricultural Experiment Station issued in 1891 and 1892 and the brief description of the nymphal form by Osborn and Ball was published in the Proceedings of the Iowa Academy of Sciences in 1897.

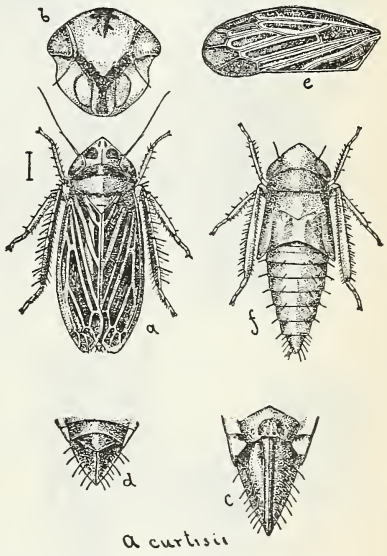

Fig. 22.—*Athysanus curtisii: a*, Adult; *b*, face; *c*, female genitalia; *d*, male genitalia; *e*, elytron; *f*, nymph. (After Osborn and Ball.)

The adult insect is 3.5 mm. in length, in body rather short and robust, the wings extending slightly beyond the tip of the abdomen. In color the head is yellow above, with two large, round, black spots above the middle, and the tip of the head is also black. The face is yellow, with an oblique black band passing from the eye to the base of the clypeus, from which it extends to the tip, forming for the whole face a Y-shaped mark. Above, the thorax is yellowish-green, with a black crescentic mark in front and the wings are dark, with distinct yellowish-green stripes. In the nymphal stage this species is stout, with a convexly conical head. The color is rather dark yellow and the eyes and antennæ are black. There is a rather dense covering of rather long hairs. (See fig. 22.)

The adults of this species appear in June and the nymphs are found during July, apparently completing their growth by the latter part of this month, and the adults are found in abundance during midsummer.

Another brood of nymphs appears during September and adults from these may be found during the autumn months, becoming abundant

in late September and mostly disappearing by the last of October. It would seem that the eggs are deposited rather early in the autumn as the adults are not found as late as those of some of the species of Deltocephalus.

The species is open to the same methods of attack as *Deltocephalus inimicus*, and for the most part the time of application would coincide very closely.

Athysanus bicolor Van D.

The species *Athysanus bicolor* Van D. has been observed more commonly and in greater abundance in southern localities than to the north, and is evidently a member of a subtropical fauna, as its distribution extends southward from the Southern States into Mexico and Central America, where it has been observed as far south as Guatemala. Its northern range is probably about to the Great Lakes, as it has been found in Maryland, Ohio, Illinois, and Iowa, west to Kansas, and then southward. Its range of food plants has not been determined with any completeness, but it does not appear to occur with any frequency on the cultivated species of grasses or grains, and hence has not the same economic importance as some of the other species.

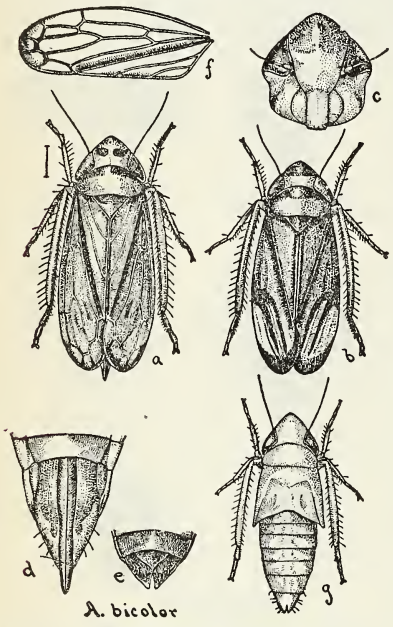

Fig. 23.—*Athysanus bicolor: a.* Adult female; *b*, adult male; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, elytron; *g*, nymph. All enlarged. (After Osborn and Ball.)

In color the females are yellowish green, with two large coalescent spots on the vertex, both margins of the pronotum, the entire claval suture, and the tip of the wing black; below, all light. The males have the whole point of the vertex, the sutural margin, and an oblique band from the anal cell to the center of the costal margin black. Below, all is black except a band across the middle of the face. This species can be readily separated from *curtisii* by the absence of the Y on the face and the fact that the yellowish-green of the elytra is not confined to the nerves. (See fig. 23.)

The nymphs are very light yellow, sometimes almost white, and the hairs are much smaller and finer than those of *curtisii*, which otherwise they closely resemble. They were first taken June 16, when the first adults of a brood were issuing, nymphs remaining abundant until the end of the month. The adults were very abundant until well

into July, disappearing before the end of the month, and appearing again toward the end of August and through September. There is nothing to be added in regard to the treatment for this species in addition to what can be recommended for the other species. Attention to the grasses in which it primarily breeds is evidently the most important consideration so far as present knowledge serves to indicate measures of control.

Athysanus obtutus Van D.

Athysanus obtutus Van D. (fig. 24) is another species with a very wide range, especially to the south and southwest, being known to

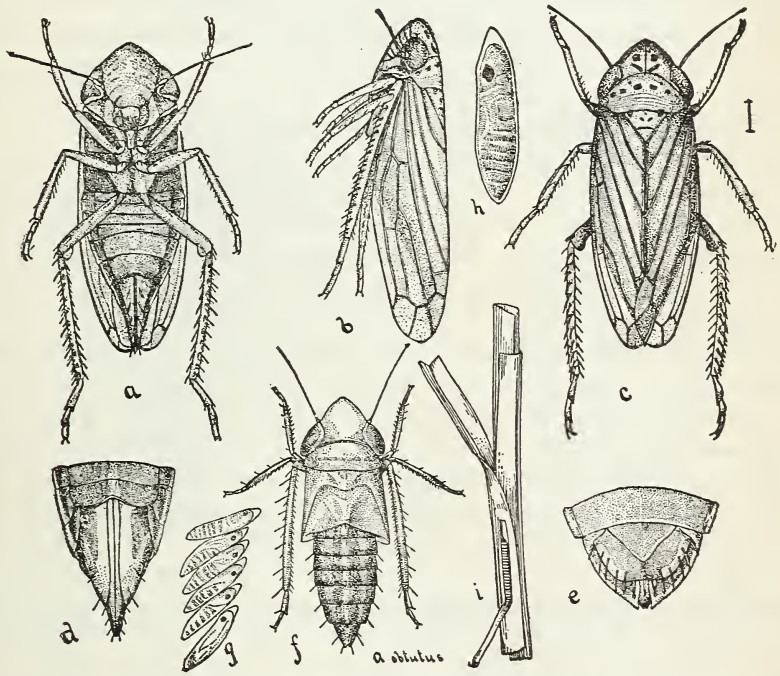

Fig. 24.—*Athysanus obtutus: a*, Adult from beneath; *b*, from side; *c*, dorsal view; *d*, female genitalia; *e* male genitalia; *f*, nymph; *g*, eggs; *h*, egg, more enlarged; *i*, eggs in grass stem, natural size. All but *i* enlarged. (After Osborn and Ball.)

occur all the way from Iowa to Central America, and from Washington, D. C., into South Carolina, Georgia, and other Gulf States.

The adults are very similar to *bicolor* in size and form, but differ distinctly in color, which is a pronounced chocolate-brown. The vertex is lemon-yellow, with two large brown spots just before the middle, and two small oblique dashes near the base darker. The apical cells of the elytra are nearly transparent, but the apical veins are distinctly blackish. The last ventral segment of the female is about the same length as the preceding segment, nearly straight or slightly concave on the hind border. The male valve is triangular; the apex is

distinctly angled and the plates short, rounded at the tips, and margined with strong bristles, the length a little over one-eighth inch. (See fig. 24, *a–e*.)

The eggs (fig. 24, *g*, *h*, *i*), which are deposited under the leaf sheath next to the stem of the plant, are elongate and slightly curved, a little thicker at the head end, which can usually be distinguished by the presence of the dark pigment of the eye spots. The nymphs (fig. 24, *f*) resemble the adults in form, but are of a light-yellow color when small, gradually becoming darker, and retaining about the same shade of brown in the last nymphal stage or pupa as prevails in the adult. The abdomen is distinctly narrower than the thorax, and the wing-pads of the later nymphal stages extend back over its base. The life history was followed at Ames, Iowa, adults being taken the last week in April, which would indicate an adult hibernation, and the first nymphs noticed in spring occurred in May and matured by the middle of June. Adults then occurred through June and the greater part of July, and full-grown nymphs, belonging evidently to the second generation, were found in the latter part of July and again before the middle of September, and adults occurred commonly throughout the remainder of the season. It would appear, therefore, that there are three broods during the season, the third one hibernating as adults, though the nymphs found in July may have been belated ones of the first brood. The food plant was determined to be *Andropogon scoparius* at Ames, Iowa, and it undoubtedly occurs on this plant as a regular thing, but adults at least have been very commonly taken on other plants. I found it in considerable numbers in wheat fields at Arlington, Va., College Park, Md., Columbia, S. C., and also fairly abundant on Bermuda grass at several points in the Southern States, especially Columbia and Clemson College, S. C. The occurrences in wheat were not so common as to indicate a very serious infestation to this crop, and unless eggs are laid in wheat in the spring the species is not likely to cause very serious damage to this crop. Very likely the adults simply migrate into wheat fields for the sake of better forage during autumn and return for the deposition of eggs to the grasses which are the ordinary food plants of the nymphal stages. The hibernating adults would be affected by burning, and this, with the use of hopperdozer or spraying, is about the only measure that can be recommended with our present knowledge of the habits of this species.

The Irrorate Leafhopper.

(*Phlepsius irroratus* Say.)

Phlepsius irroratus Say is one of the most abundant and widely distributed species of the genus, occurring all over the eastern United States from the extreme north to the Gulf and westward to the

Rocky Mountains. It is dark brown, the surface minutely irrorate on the vertex and pronotum, and with numerous fine reticulations or irrorations on the wings. (See fig. 25.) It is nearly one-half inch in length.

The life cycle of the species is not known in detail, but the nymphs occur quite commonly in grassland, meadows, pastures, and sometimes in wheat fields during the latter part of the summer. They are rather flattened and are more or less distinctly irrorate, with minute patches on the head, pronotum, and abdomen. Figure 25, *f*, represents a nymph taken at Toledo, Ohio, associated with the adults, and where other species were not present, so that there can be little doubt as to its being the nymph of this species. Such nymphs have been taken in many cases associated with adults of *irroratus* where

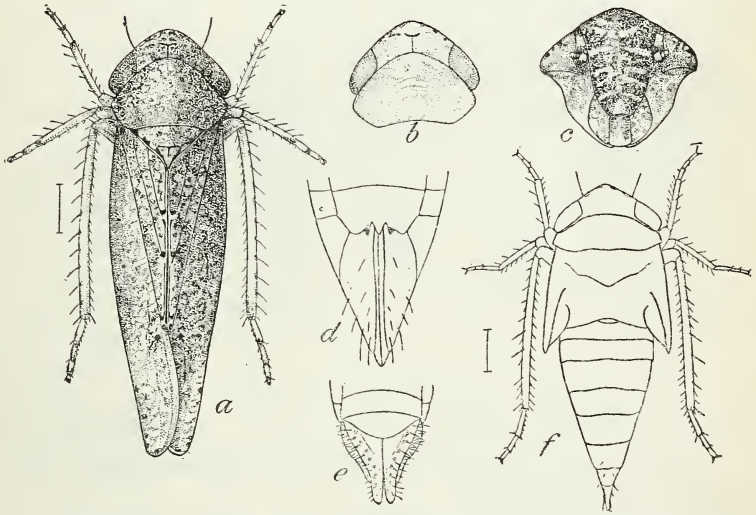

FIG. 25.—The irrorate leafhopper (*Pàlepsius irroratus*): *a*, Adult; *b*, vertex and pronotum; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, nymph from specimen taken at Toledo, Ohio. All enlarged. (Original.)

the species is abundant and at widely separated localities, so that there is practically no doubt as to its identity, although no rearing of the nymph has been made.

While the species is abundant throughout the Eastern and Central States and indeed throughout its entire range, its economic importance is not fully recognized since it occurs in quite general distribution and has never been recorded as swarming in any one particular place. It is hardly possible to collect leafhoppers in any part of the country, especially during late summer and autumn, without finding an abundance of this species, and it is certain that they must cause some injury in the crops which they affect. As mentioned on a preceding page, it was observed by Herbert T. Osborn swarming toward evening around trees at Urbana, Ill., in the autumn of 1909. It is

found especially in wheat fields, in clover, and grass, and has evidently a rather wide range of food.

Since it is so generally distributed, it is not such a simple matter to control it, but to some extent it could doubtless be controlled by the burning of the strips of grassland adjacent to fences, and especially in the South this should serve as a considerable relief from its attacks on winter wheat.

The Geminate Leafhopper.

(*Thamnotettix geminatus* Van D.)

The geminate leafhopper (*Thamnotettix geminatus* Van D.) has been recognized as of wide distribution, but hitherto has not figured in economic literature. It appears, however, that it must be taken into account hereafter since it has occurred in such numbers upon clover, alfalfa, and timothy in the State of Washington, especially at Pullman, as to threaten to become destructive.

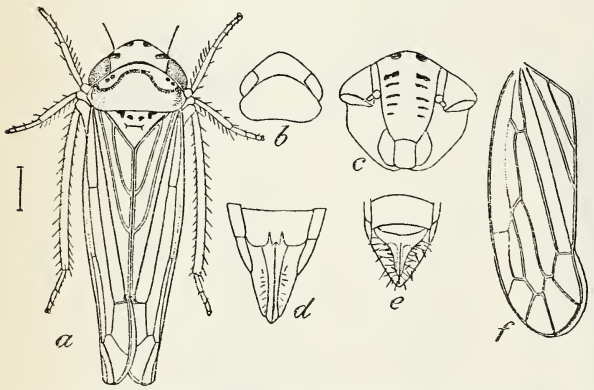

Fig. 26.—The geminate leafhopper (*Thamnotettix geminatus*): *a*, Adult; *b*, vertex and pronotum of male; *c*, face; *d*, female genitalia; *e*, male genitalia; *f*, elytron. All enlarged. (Original.)

It was first described from California and later recorded for Colorado (Dolores, C. P. Gillette), both these localities being cited by Van Duzee in his catalogue.

Under the name *Cicadula læta* it was recorded from Alaska and Shumagin and Popoff Islands by Ashmead in his report on the Homoptera of the Harriman expedition of 1898. Specimens under this same name also are in the National Museum from Ungava Bay, Territory of Ungava. The species is therefore of wide range and should it readily adapt itself to cultivated crops might easily become a serious pest. So far, and except for the California localities, it appears to have been restricted to the northern regions or to higher altitudes of the plateau region.

It is of a clear greenish-yellow color, the head having a pair of conspicuous black spots on the anterior border, another each side next the eye, and a conspicuous arched band near the front border of the pronotum. (See fig. 26.) The length is from 5 to 6 mm. The life history has not been traced.

The native food plant of the species is not known to me, but from its apparently ready adaptation to clover and alfalfa one would sus-

pect that it occurred primarily on some of the indigenous legumes of its original habitat.

The Six-spotted Leafhopper.

(*Cicadula 6-notata* Fall.)

The widely spread six-spotted leafhopper (*Cicadula 6-notata* Fall.) was described in Europe more than a century ago, and the references in systematic literature by Curtis, Flor, Germar, Kirschbaum, Fieber, Marsh, Melichar, and others show it to have been a common and well-known, and apparently a widely dispersed species in that country during the past century. Little seems to have been done with it from an economic standpoint. Leonardi, in the Italian work on Injurious Insects in Italy (Gli Insetti Nocivi), makes mention of it as an enemy of cereals but with no discussion of habits or modes of treatment. Edwards in a systematic work on British Homoptera records it as "very abundant on grasses." Doubtless many other such records occur scattered through the European works on insects, but a thorough discussion of the species for economic purposes seems never to have been given. Considering the present distribution of the species over the whole United States, including Alaska, its history in this country becomes a matter of great interest.

The first published record of occurrence of the species in America appears to be that of Forbes in 1884, followed by Woodworth (1885) and Provancher (1890), and there is a record in the Bureau of Entomology for Lafayette, Ind., by Prof. F. M. Webster, dated November 30, 1885.

Unfortunately we can not safely assume that lack of record by earlier entomologists is in this case any positive proof that the species was not present. While Say, Harris, Fitch, and Uhler all gave attention to this group of insects, and their studies together run back to 1820, they naturally could not be expected to recognize all that might have occurred, even in their respective localities. However, absence of records, especially in the case of such good collectors and acute observers, is in some degree presumptive evidence of nonoccurrence in the case of a species so abundant as this, and if we assume an introduction of the species at some period closely prior to its first notice we must recognize a rapid spread over the whole country, as it is stated by Van Duzee in 1894 to "occupy North America from Ontario and Connecticut to Alaska and California and south to Mississippi." There is in the records concerning the species in this country no sequence of dates which furnishes us any basis for tracing any dispersal from some center of introduction, as records for such

widely separated points as Illinois, Iowa, Ontario, Washington, D. C., California, and Tennessee appear all within five years of its first notice.

In this connection the unpublished records of the Illinois State entomologist, which were kindly placed at my disposal by Prof. Forbes, are of special interest. These records show the species to have been taken from wheat, oats, or grains, etc., in Illinois at the following places: Carmi, October 6, 1882; Cuba, May 15, 1883; Decatur, May 23, 1883; Bloomington, May 24, 1883; Normal, May 28, 1883; "S. Ill.," August, 1883; Centralia, August 7, 1883; Cherry Valley, August 17, 1883; and at West Union, Mt. Carmel and Marshall in May, 1884. This would show the species to be distributed over the entire State and to be well established, as in many cases the specimens in the collection are in large numbers and indicate an abundance in the field. The published record, moreover, speaks of them as in destructive numbers.

I took it in great numbers in Washington, D. C., in July, 1890,[1] and it appears in my list of Iowa species of Jassidæ in 1892.

In the Hemiptera of Colorado (1895) the species is recorded from Colorado Springs, August 1, and Fort Collins, July 24.

The National Museum shows a single specimen labelled "C. Mo. June" without date, evidently from the old Riley collection and probably collected before 1880; specimens from Los Angeles County, Cal., collected by D. W. Coquillett, which must have been taken between the years 1886 and 1893; others by Koebele, Sacramento and Placer Counties, Cal., certainly since 1880; one from San Francisco, Cal., June 24, 1885; one from Massachusetts, no date, but evidently a recent specimen, and another from Cimarron, Kans., 1891.

Bureau records or specimens show it to have been taken within the last five years at Clemson College and Spartanburg, S. C.; Hamilton, Ala.; Dallas and Denison, Tex.; Mansfield, Ark.; Mesilla Park and Springer, N. Mex.; Wellington and Manhattan, Kans.; Kingfisher, Okla.; and Tower City, N. Dak.

In March, 1909, Mr. Harper Dean reported as follows:

Denison, Tex., March 22, 1909, drove 4 miles from town to farm of Mrs. Della Cramer, whose small field of barley, about one-fifth acre, had been killed outright, a week or ten days previously, supposedly by Toxoptera. No sign of the latter could be found, but there was an abundance of Jassidæ, all of one species. She said these were the prevalent insects at the time of the outbreak. Took a number of specimens and determined them by Dallas collection as *Cicadula 6-notata* Fall. Gave Mr. Tucker some of these specimens, brought remainder to San Antonio. The latter were so mutilated en route that only a single specimen was good. Sent this to Prof. Webster.

I found it generally distributed for the season of 1909, northwest to Washington State and southeast to South Carolina and Georgia.

[1] See Insect Life, vol. 4, p. 197.

In the Dakotas it was usually the most abundant species in fields of wheat, oats, and barley, as well as the most universally present, but it was not in such numbers as to be counted destructive. At Dickinson, N. Dak., it was found on millet as well as on wheat and oats. It occurred at Mammoth Hot Springs, Yellowstone Park, in a small patch of cultivated grass; at Bozeman, Mont., on wheat, oats, barley, and timothy; at Missoula, Mont., on tame grasses; at Pullman, Wash., on Festuca; at Kalispell, Mont., and Williston, N. Dak., on wheat, oats, alfalfa, clover, millet, and brome grass; at Castalia, Ohio, August 13, in volunteer wheat; at Toledo, Ohio, August 13, in Hungarian grass; at Valencia, Harrisburg, and Reading, Pa., in wheat or grass; at Arlington, Va., November 12; at Raleigh, N. C., November 15; at Columbia, S. C., November 16; at Clemson College, S. C., in wheat, rye, and barley, November 17; at Knoxville, Tenn., in barley, November 22. All these records represent adult stages, and adults have been observed every month from March and June to November.

The life history of the species has never been given in detail, though brief statements concerning the nymphal period appear in some cases. Leonardi barely mentions "larva and nimfe" in connection with reference to the species as a pest to cereals. Some work was done on the life history at Ames, Iowa, years ago, but no publication was made, as it was hoped to complete lacking details.

There is little separation into distinct broods, and adults, as shown by records above, are to be found throughout the season, probably because of the short period of development of the young. In Texas adults, as shown in reports above, were abundant March 22. Webster gives a record of adults, confined on wheat kept indoors, which deposited eggs on November 11, the latter hatching November 27; and a further note on the last-stage nymph, December 24, would indicate the passing nearly to adult stage within a period of about six weeks, with indoor conditions. With present data, it seems impossible to determine definitely the number of generations during a season.

The adult insect is of a light greenish-yellow color, the head marked very distinctly with black dots or spots arranged in pairs, two round spots on the hind part of the vertex, a pair of transverse spots a little in front of the middle, and another pair, also transverse, at the border between vertex and front. The front is marked with black curved lines, and the sutures are black. The elytra are nearly transparent, the veins showing as lighter lines near the base and darker lines toward the apex, which also is somewhat smoky. The body above is black, the border of the abdomen yellow beneath, the body yellow, with black for the central part of the thorax and the basal portion of the abdomen.

The last ventral segment in the female is yellow, slightly longer than the preceding segment and slightly convex on the hind border. The pygofer is yellow; the ovipositor is black and equals the pygofer in length. In the male the last two ventral segments are whitish, somewhat hairy; the valve short, slightly angular; the plates nearly triangular; tips acute, scarcely reaching the end of the pyfoger. The length is about 3.5 to 4 mm. (See fig. 27.)

The nymphs are pretty easily distinguished by the markings on the head, which are very similar to those of the adult. The color is

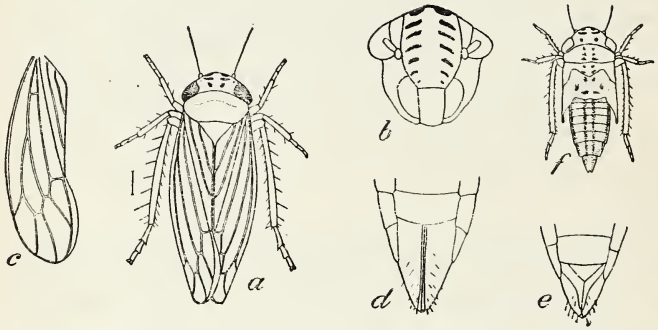

FIG. 27.—The six-spotted leafhopper (*Cicadula 6-notata*): *a*, Adult; *b* face; *c*, wing; *d*, female genitalia; *e*, male genitalia; *f*, nymph. All enlarged. (Original.)

usually a darker green, the head is more rounded, and the abdomen is slender. A separation into the different molts has not been secured.

The adults fly readily and probably to considerable distances, and at least two records, one in Kentucky and the other in Tennessee, show it to be attracted to light.

The ready migration may lessen the efficiency of rotation and clean culture, yet it was noticeable that very few were to be found in fields where recent planting or clean culture were the rule. The hopper-dozer methods would probably serve well in places where they can be applied.

EMPOASCA MALI Le Baron.

Empoasca mali was first described by Le Baron as a pest to the apple, and it has received considerable attention at various times in this connection and as a pest to various woody plants. It is also at times very destructive to other crops, having been noted on potatoes (Osborn), beans (Gillette), soy beans, cowpeas, alfalfa, clover, etc.

The insect is about 3 mm. in length, of a light grass-green color, usually quite brilliant and sometimes iridescent, this color prevailing throughout the entire body, but there is a series of whitish spots along the front margin of the prothorax, usually six in number, and

two whitish lines or stripes on the mesothorax which unite near the center by a transverse band, forming the letter "H." A small triangular white spot occurs on the scutellum with a small dot on either side. The eyes are brilliant white when the insect is alive, but turn to a dull brown in dried specimens.

The species, according to recent studies, appears to have three or four generations each year, and to pass the winter either in the adult or egg stage, a diversity of habit and life cycle which would seem to indicate its derivation from some other geographical region, or an adaptation to varied food plants furnishing it supplies of nutrition throughout the year. Such a diversity renders it more difficult to apply direct measures of control. Upon soy beans it occurs in the nymphal form during August and early September, and mature individuals are abundant in September and October which may deposit eggs, or very likely secrete themselves for hibernation during the following winter. A number of recent records show its occurrence on alfalfa and cowpeas, and in some instances I have noticed considerable injury to these crops as the evident result of its occurrence.

There are a number of reports of its injuries to forage crops and a few of these may be cited as example of the character of its work. At Clemson College, S. C., July 15, 1908, Mr. G. G. Ainslie reported that at the experiment station he found a lot of soy beans affected with a green leafhopper. He says: "They were present in great numbers in all stages, and many of the leaves were corrugated and curled by them. The lower leaves are yellowish. When the beans are disturbed, the hoppers fly out in clouds." The specimens collected and preserved in alcohol were identified as this species.

At Lexington, Ky., Prof. Garman records extensive injury to alfalfa, and notes a variety of food plants and that the insects migrate during the season, seeking fresh growth and succulent plants. He says that there are several generations. It occurs on clover and alfalfa in June and July and again in September. It is also destructive to cowpeas, and another record gives it as occurring on red clover.

At Lafayette, Ind., I found it common on soy beans and alfalfa October 5, and Mr. Phillips informed me that it was common and abundant on soy beans earlier in the season, and he attributed injury to the crop to its presence. As most of the varieties of the soy beans had ripened at the time of my visit I saw the insects on only one variety of soy bean but found them as both nymphs and adults, which would show that they develop on this plant. On alfalfa they were much more plentiful and included nymphs of different stages as well as adults. More recently, during the summer of 1911, Prof. Webster reported to me a serious infestation on the farm of Dr. H. W. Wiley, near Bluemont, Va., where the plants were entirely destroyed above ground.

The species was reported from Sharonville, Ohio, by Mr. L. E. Shepherd, June 17, 1910, with the statement that "it attacked second crop of alfalfa and it is turning yellow from the effect."

These various records show a ready adaptability to the alfalfa, and indicate that the species must be reckoned with in the growing of this crop.

THE NYMPHAL STAGES.

The nymphs are light green, often with a yellowish tinge, and are found usually upon the underside of the leaves of the plants which they infest, clustered commonly beside the midribs and main ribs of the leaf, where they suck the juices of the leaf.

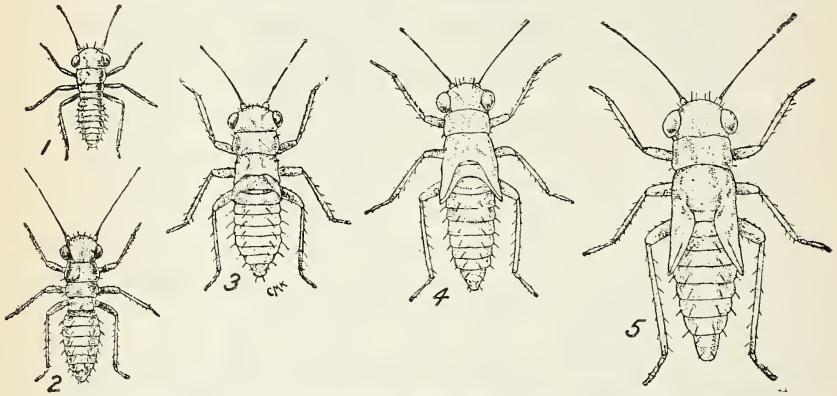

FIG. 28.—*Empoasca mali:* Five nymphal stages. All enlarged. (After R. L. Webster.)

The stages (see fig. 28) are described by Mr. R. L. Webster, as follows:

Stage I.

Length 1 mm. (average of 10 specimens).

Head, thorax, abdomen, and legs pale when first born. After the young hopper has taken some food into the body, the abdomen takes on a yellow color. The eyes are dull reddish. Two rows of six spines are on either side of the meson; one dorso-laterad, one ventro-laterad, in position; one spine in a row to the segment. Spines small, pale. Caudal border of metathorax blunt in outline.

Stage II.

Length 1.26 mm. (average of 10 specimens).

Head, thorax, abdomen, and legs pale green; eyes dull reddish, antenna, segments I and II pale, remainder dusky. Caudal border of metathorax sharp in outline.

Stage III.

Length 1.56 mm. (average of 10 specimens).

General color pale yellow, orange on dorsum of abdomen. Eyes dull reddish. The wing pads now appear quite distinctly and reach to the caudal border of the first abdominal segment.

Stage IV.

Length 1.86 mm. (average of 10 specimens).

Head and thorax pale; abdomen pale yellow; eyes dull brownish. The wing pads now extend to the caudal extremity of the second abdominal segment.

Stage V.

Length 2.26 mm. (average of 10 specimens).

This stage is rather broader than IV. Head, thorax, and wing pads pale green; abdomen dull yellow; eyes dull brownish. The wing pads extend nearly to the caudal border of the fourth abdominal segment. Antenna; I and II pale green, remainder dusky.

DISTRIBUTION.

The species is universally distributed over a considerable part of the United States. Records of collection have been made for practically all the points at which collecting has been done in the Mississippi Valley and Atlantic slope regions.

TREATMENT.

The control of the insect is rendered more difficult because of the large variety of plants upon which it may feed, and its ready migration from one to the other. Upon potatoes, alfalfa, and other low-growing crops the use of kerosene spray is perhaps the most available direct treatment, but for large areas this is a rather expensive process. Moreover, its most successful application is limited to times when the crop is young or short enough so that the spray may reach the foliage thoroughly. The treatment of apple trees or nursery rows, where it is often especially injurious, must be accomplished by the use of especially devised hopperdozers or shields carried along the rows in such manner as to dislodge the hopper, or by the use of spraying machinery especially devised for this kind of application.

The Clover Leafhopper.

(*Agallia sanguinolenta* Prov.)

The clover leafhopper (*Agallia sanguinolenta* Prov.) (fig. 29) is one of the most abundant and widespread species of American jassids, but very little has been done in the matter of working out its habits and life history and that little within the last two decades. It was described by a Canadian entomologist, Abbé Provancher, in 1872 and later, 1876, was again described by Prof. Uhler and has been several times referred to in later papers under the name *Bythoscopus siccifolius* Uhler. Possibly some of the references to *novellus* Say included this form as it must have been an abundant species in earlier days. It was treated as a grass insect in 1890 in an article by the writer.[1] It was discussed, included, and figured as a sugar-beet insect by Prof. Bruner in a bulletin on sugar-beet insects in 1891[2] under the name *Agallia siccifolia*, and in November of the same year the writer treated of and figured its various stages as a clover pest and also mentioned it[3] as a sugar-beet pest under the name now used. As this account gives substantially what is known concerning the life history and

[1] Bul. 22, o. s., Div. Ent., U. S. Dept. Agr., 1890.
[2] Bul. 16, Nebr. Agr. Exp. Sta., Apr., 1891.
[3] Bul. 15, Iowa Agr. Exp. Sta., 1891.

habits and as the bulletin is no longer available for distribution I quote directly from that article.

April 15th, we confined several in a breeding jar upon growing blue-grass. April 24th, they were observed copulating. April 26th, all were dead. Where they fed upon the blue-grass their punctures appeared as small white spots, the epidermis only remaining about the point from which they had sucked the nutritive juices of the blade.

April 27th, some specimens taken in copulation in the field were confined on growing clover. Their liking for the clover as compared with blue-grass was very apparent and we had no difficulty in carrying them forward on this food plant. They preferred to feed by inserting their beaks in the petioles, or stems, of the leaves, in which position they would remain motionless for hours at a time sucking out the juices of the plant. They would also sometimes feed upon the blade.

The wilting of the clover from their incessant drains upon it was evident and it was only by frequent and generous watering that it was kept growing. By the middle of May few specimens could be found outside of clover fields and sweepings made at intervals throughout the summer failed to disclose them elsewhere in sufficient numbers to attract much attention. During October they could again be found in blue-

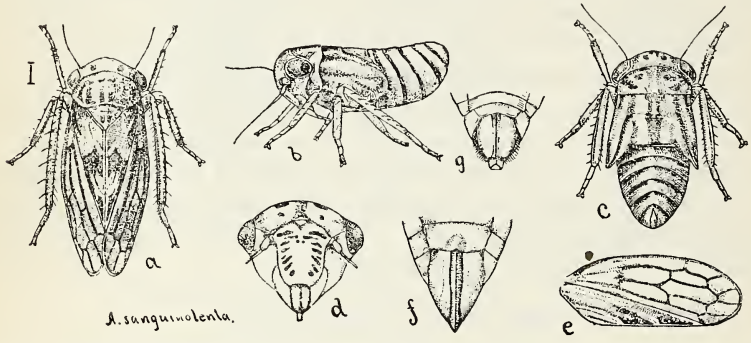

FIG. 29.—The clover leafhopper (*Agallia sanguinolenta*): *a*, Adult; *b*, nymph, side view; *c*, nymph, dorsal view; *d*, face; *e*, elytron; *f*, female genitalia; *g*, male genitalia. All enlarged. (After Osborn and Ball.)

grass patches and about weedy spots to which they migrate on the approach of winter, or perhaps as soon as their favorite food plant begins to show the effects of cold weather.

From their numbers in this locality and their method of attack we should count them among our most serious clover insects.

The first larvæ were found in our breeding jars May 20th. They much resemble the adults except that they are smaller and nearly white in color. A few eggs were observed inserted beneath the epidermis along the midrib of the blade. Most of the eggs must have been laid elsewhere, however, probably among the bases of the petioles about the crown of the root, or beneath the epidermis on the petiole where they would not be easily discovered. June 9th, the wings of the older nymphs nearly covered the body and by the first of July they were mature. Hatching at this time was still in progress, so that we had every stage in the life-history of the insect represented at the same time in our cages. Nymphs in all stages were found from this date until late autumn, the new adults doubtless beginning egg-laying in July, or August, and the larvæ of the first brood would be maturing all through the months of July, August, and possibly September. The earliest adults of the second brood might have time to oviposit and produce a third brood in autumn, some specimens of which could mature, but we have no doubt that the great majority of the insects are included in two broods. This conclusion seems probable to us from the rate of growth, and the fact that few nymphs are to be seen late in fall. We have found none in spring and think that the belated ones of fall perish during the winter.

Distribution is general from New England through southern Canada, Washington, and Oregon and south to Georgia, Mississippi, and Vera Cruz, Mexico, and west to Arizona and California.

It affects a wide range of crops, as might be inferred from mention already made, but it shows a preference apparently for clover, alfalfa, and other legumes and so far the nymphal stages have been taken almost exclusively on plants of this group. During the season of 1909 it was observed in stubble with grass and clover at Grand Forks, N. Dak. July 28. It was found at different points in Ohio in August and September—at Cedar Point during August; at Wooster during September, in stubble-fields, including clover. At Lafayette, Ind., on October 5, it was found on alfalfa; at Harrisburg, Pa., November 5; at Reading, Pa., on November 6, in pasture and in wheat; at College Park, Md., on November 11, in grass strip next to wheat; at Arlington, Va., on November 12, in wheat plat; at Washington, D. C., on November 13, in leaves (?); at Raleigh, N. C., on November 15; at Columbia, S. C., on November 16, in wheat; at Knoxville, Tenn., on November 22, on alfalfa and red clover; at Maysville, Ky., on December 4, in wheat, near border of field. While not in excessive numbers in any of these localities it was often abundant enough to be considered as a distinct drain on the crop. In every case where it was observed in wheat fields it was in the adult stage and had very certainly migrated thither from adjacent pastures and meadows. Probably in none of these was clover entirely wanting, and I believe we may safely base measures for avoiding injury to wheat or other fall-planted crops on the assumption that it comes from near-by meadows or pastures that have been a year or two at least in grass and clover. As for the injury in clover fields or alfalfa, I believe this to be very considerable not only in checked growth but very probably in lessened seed production from its attacks on the blossoms and newly forming seed. Herbert T. Osborn, of the Bureau of Entomology, reported it as abundant and apparently the most injurious jassid in alfalfa at Wellington, Kans., in the winter and spring of 1910.

This species is closely related to the *Agallia venosa* Fall., of Europe, which, according to Edwards, is "very common at the roots of grass, etc." This would indicate a similarity of habit and possible derivation from a common ancestral form.

The adaptation in our species to clover and alfalfa, which are both introduced plants, may therefore have been an easy matter since it probably fed upon some native legume before these plants were available. The increasing abundance of the species on adaptation to a new food plant simply follows a very general law with reference to the adaptation of native insects to introduced crops. Considering the present distribution of the species, and especially in its relation to other species of the genus, it seems probable that it has migrated from

a southwestern habitat since introduction of its host plants. Such a history would accord well with the fact that no mention of the species was made by Say or other writers during the first three-fourths of the nineteenth century. It seems hardly possible that it could have escaped them if it had occurred in its present abundance and wide distribution. In whichever direction it may have been dispersed it seems quite certain to have been in connection with cultivated crops, as it does not occur in the uncultivated areas to which some of its congeners seem well adapted. A similar tendency to adopt alfalfa and clover is, I believe, manifested by *Agallia uhleri*, which recently has been taken in abundance on these crops by Mr. C. N. Ainslie at Mesilla Park, N. Mex.

TREATMENT.

Owing to the habit of adult hibernation, the winter or early spring burning of rubbish and dead leaves where they occur is likely to be quite effectual in their reduction and where they occur in destructive abundance the spraying of alfalfa or clover fields directly after cutting a crop should be of distinct advantage.

The species has been noticed to harbor considerable numbers of minute hymenopterous parasites, probably of the genera Dryinus or Gonatopus, and it is very likely that these parasites assist in keeping their numbers within such bounds as to prevent very notable injuries.

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